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*Containing the papers read at the meeting
held at
Philadelphia, Pa., February 23rd, 24th, and 25th, 1920,
together with
supplementary discussions and
other matters*

Homer F. Staley, Editor

*This Society is not, as an organization, responsible for the statements of facts
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EDITORIALS

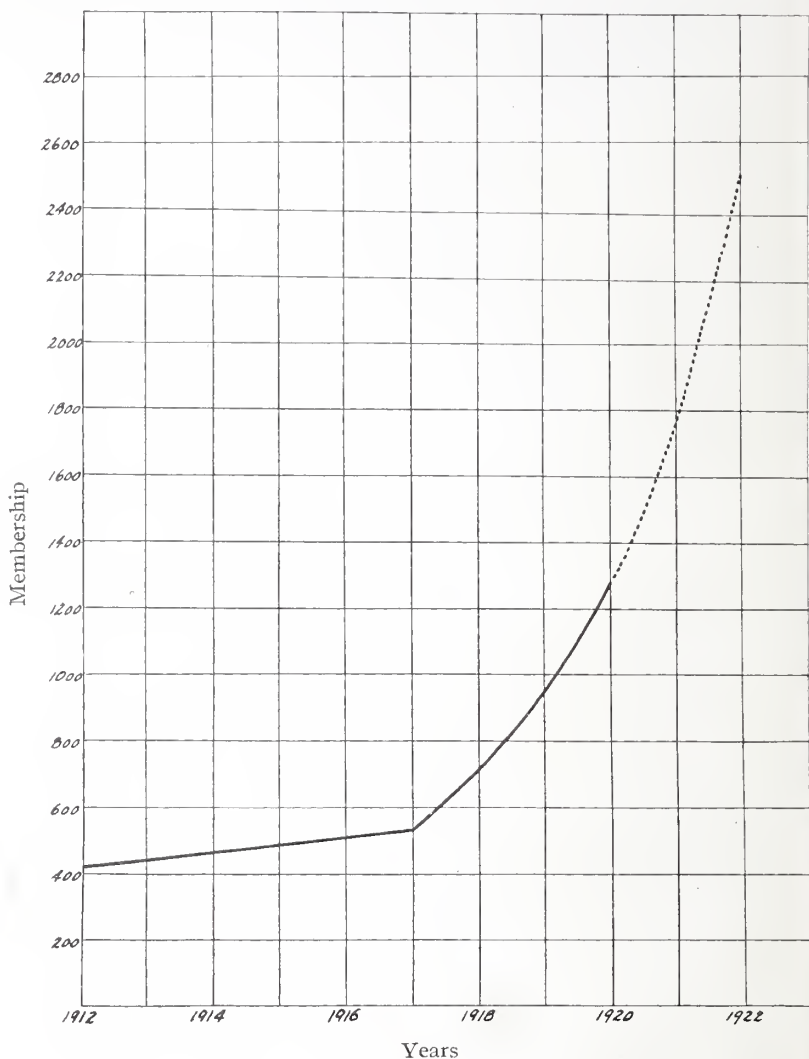
MINIMUM OF 2500 MEMBERS BY JANUARY 1, 1922

The accompanying graph shows the growth in membership of the American Ceramic Society during the past eight years. It will be seen that the growth from 1912 to 1917 corresponds with the slow rate of increase in membership during the first eighteen years of the life of the Society. With the annual meeting in 1917, came the reorganization of the Society and energetic prosecution of activities along a diversity of lines, including the launching of the Journal. From that time on growth has been rapid.

A noticeable and very important feature of the growth during the last three years is that the total increase each year has been greater than that of the preceding. During 1917, 216 new members were gained; in 1918, 226; and in 1919, 284. This results in a concave curve when the total membership is shown in graph form. This concave form of the curve is very encouraging, since it shows that we are gaining momentum. It also places a greater responsibility on the present membership if the form of the graph is to be maintained, for it means that a rapidly increasing number of members must be obtained each year. It means that we must gain 540 new members during 1920 and 700 during 1921. In other words, we must secure approximately twice as many members during the present year as we did last year and three times as many next year.

The growth in membership that we expect during the next two years cannot be obtained merely by solicitation. *It must be earned.* It will not come merely by strenuous activity of the mem-

bership committee, although such activity will be necessary. It must come as the result of energetic and effective work by every



officer, every committee and every member to make this Society of greater service to the ceramic industry. By officers and com-

mittees we mean not only those of the general Society, but also those of the various Divisions and Sections.

The field for obtaining new members is ample. There are over 250,000 people engaged in the ceramic industries of this country. If we attain to 2500 members by the date set we will have less than one member for each 100 persons engaged in these industries. If the Society becomes the great technical organization that it should, and that we intend to make it, the ratio of members to persons in the industries should be much higher than this. Twenty-five hundred members by January 1, 1922, is to be considered as the permissible minimum consistent with healthy and normal growth of the Society and not as the maximum.

Does it not seem then that each of us should take stock of our possible abilities, not our abilities when we are lazy and indifferent, but when we throw ourselves whole-heartedly into an effort to attain some goal? Let each of us do the one thing that lies in our power to make the Society as efficient and serviceable as possible. If we do this the American Ceramic Society will deserve at least 2500 members by January 1, 1922, and *it will get them.*

A CALL FOR LEADERS

At present our membership in certain branches of the ceramic industry, such as the cement, the lime, and the brick and tile, is small. The activities of the Society in behalf of these branches and the amount of service we are giving to these industries should be increased. The work of the Society in other directions, also, can well be expanded. We have the facilities and the ability to do this. All that is lacking is leaders with enough vision to perceive the opportunities and with sufficient courage to undertake the tasks. That such men will be found is evident by the success the Society has had in the past three years in finding men to conduct its committee work, to organize divisions and to form local sections. The most remarkable and the most stimulating feature of the life of the Society during this period has been the large number of men, especially of comparatively young men, that by right

of efficiency and of devotion to the interests of the Society have earned positions as leaders in the Society's work. Such men are the most valuable asset of the Society at present and its most substantial assurance of growth and development in the future.

If the Society is to maintain its present rapid rate of growth and expand its field of service, it is imperative that leaders be found to conduct its activities along lines and in fields hitherto neglected. These men must be found not in two years from now, nor in one year, but immediately. It is difficult for the Board of Trustees to find these men, for, like gold, ability and devotion is often found in unexpected places. This is no time for undue modesty, and we may feel assured the Board of Trustees will be very glad indeed to have any man who wishes to work for the good of the Society volunteer for service. Place and the opportunity will be found for him.

OUR PLATFORM

1. To make this Journal indispensable; to make it so serviceable that no one in this country who is interested either intellectually or financially in any phase of ceramic technology can afford *not* to be a conscientious reader of the JOURNAL OF THE AMERICAN CERAMIC SOCIETY.

2. To make this Journal the great technologic journal of the ceramic industries of this country, not a trade paper on the one hand nor a scientific publication on the other, but a true technologic journal, to which the contributions of the trained scientist and of the factory man, richly endowed with ideas and data by practical experience, must be sent in order to reach an appreciative audience.

3. To make this Journal a comprehensive and timely abstract journal, one that each month shall contain in its abstract department a summary of the progress during the previous month of the whole world in ceramic technology.

4. To make this Journal an impelling force in the growth and development of the Society, by keeping the membership as a whole informed of the various activities of the Society and by holding our editorial columns open to any one who has a message

that will make the members *think* about the welfare of the Society. We do not care whether his ideas are in accord with our own or not. As long as the members *think* about the welfare of the Society it is bound to prosper.

5. To keep this Journal as far as possible mechanically perfect and rhetorically correct, not that we consider form as important as substance, but because good form in composition adds to the pleasure of reading and is due the dignity of a high-class technical journal.

6. To make this Journal a valuable and well patronized advertising medium. This will be a logical result of the successful accomplishment of the foregoing.

ORIGINAL PAPERS AND DISCUSSIONS

THE USE OF SUBSTITUTES FOR TIN OXIDE IN GLAZES

BY R. H. MINTON

A search of our *Transactions* reveals that little work has been done with substitutes for tin oxide in glazes, outside of the enameled iron field. In enamels for cast iron and sheet steel the principal substitute for tin oxide has been antimony oxide. A review of the *Transactions* develops the following references:

J. B. Shaw, in "The Allowable Limits of Variation in the Ingredients of Enamels for Sheet Steel," Vol. XI, p. 151, says: "SnO₂ produces opacity alone, but it may be entirely replaced with ZnO plus Sb₂O₃, with equally good results; 0.13 equivalent of ZnO plus Sb₂O₃ or SnO₂ is sufficient to produce a good white opacity by using two coats of white."

Homer F. Staley, in "The Control of Fusibility in Enamels," Vol. XIII, p. 506, states: "While bone ash can be used as a weak opacifying agent to some extent, it is liable to cause minute pinholes in the enamel and vesicular structure in any part of the piece that should happen to be overheated."

R. E. Brown, in "The Replacement of Tin Oxide by Antimony Oxide in Enamels for Cast Iron," Vol. XIV, p. 752, writes: "The effect of Sb₂O₃ is to increase the maturing temperature, and to increase the whiteness and opacity when employed between the limits of 0.0-0.9 equivalent Sb₂O₃." To produce a good white with SnO₂ 0.15 equivalent was required.

Homer F. Staley, "Antimony Compounds as Opacifiers in Enamels," Vol. XVIII, p. 188: "Oxide of antimony enamels of good gloss can be made." "Opaque whites are produced by controlling the heat treatment and composition."

Emley and Young, "The Production, Manufacture and Use of Compounds of Barium," Vol. XVIII, p. 247: "Barium salts are also used extensively in the preparation of mat glazes. An important use of barium is in the manufacture of enamels for iron. When tin oxide is used as an opacifier, the presence of barium is very desirable. . . ."

Ercill C. Hill, "White Terra Cotta Glazes at Cones 6-7," Vol. XVII, p. 383, found that: "The opacity and white color of the glazes increases with the increase of SnO_2 . It also increases with increase of ZnO , and with increase of BaO when the ratio of CaO to BaO is less than 1 : 1. Increase of SnO_2 is more effective in increasing opacity than either ZnO or BaO ."

Kirkpatrick, Arnold and Geiger, "An Attempt to Fit Enamels to Plastic Clay Bodies," Vol. XVIII, p. 145, found that 0.12 equivalent of SnO_2 was sufficient to produce opacity in an enamel for bricks.

J. B. Shaw, "Antimony Oxide as an Opacifier in Cast Iron Enamels," *J. Am. Ceram. Soc.*, Vol. I, p. 511, asserts that: "Extreme care in proportioning the raw materials, very careful and thorough mixing, and proper smelting, will insure the successful use of antimony oxide."

Homer F. Staley, "Enamels for Cast Iron," *J. Am. Ceram. Soc.*, Vol. I, p. 706, says that sodium metantimonate has been extensively used in America during recent years as an opacifying agent for cast iron enamels which are leadless, or with low or medium lead. He states that "The essential difference between sodium metantimonate enamels and those in which the oxide of antimony is used as the chief opacifier is that the latter contain much larger amounts of sodium nitrate."

These references show that practically all of the investigations into the matter of substitutes for tin oxide as an opacifier has had to do with enamels for metals. The work done by Hill in the field of terra cotta glazes covers the ground very well, but he tried only ZnO and BaO to determine their effects upon SnO_2 .

Scope of this Investigation.—In the work under consideration twelve different substitutes were used to replace tin oxide in four

different types of glazes. The corresponding number in each of the four series contains the same opacifier.

SERIES R.—Raw lead glaze at cone 02

| | | | Batch weights |
|----------------------|-------------------------------------|----------------------|------------------|
| 0.70 PbO | | | 167.7 White lead |
| .10 K ₂ O | 0.15 Al ₂ O ₃ | 1.7 SiO ₂ | 55.7 Feldspar |
| .10 CaO | | .10 SnO ₂ | 10.0 Whiting |
| .10 ZnO | | | 8.1 Zinc oxide |
| | | | 12.9 China clay |
| | | | 54.0 Flint |
| | | | 14.9 Tin oxide |

SERIES F.—Fritted wall tile glaze at cone 02

| | | | Batch weights |
|----------------------------|-------------------------------------|------------------------------------|------------------|
| Frit 0.24 K ₂ O | | | 133.7 Feldspar |
| .28 Na ₂ O | 0.24 Al ₂ O ₃ | 3.56 SiO ₂ | 123.6 Flint |
| .48 CaO | | 1.12 B ₂ O ₃ | 48.0 Whiting |
| | | | 106.9 Borax |
| | | | 69.4 Boric acid |
| Glaze 0.49 PbO | | 2.25 SiO ₂ | 193.5 Frit |
| .12 K ₂ O | 0.19 Al ₂ O ₃ | .571 B ₂ O ₃ | 126.4 White lead |
| .15 Na ₂ O | | .10 SnO ₂ | 18.1 China clay |
| .24 CaO | | | 19.5 Flint |
| | | | 14.9 Tin oxide |

SERIES T.—Terra cotta raw glaze at cone 6

| | | | Batch weights |
|------------|--------------------------------------|-----------------------|-----------------|
| 0.200 KNaO | | | 111.4 Feldspar |
| .375 CaO | 0.325 Al ₂ O ₃ | 2.50 SiO ₂ | 37.5 Whiting |
| .175 BaO | | .10 SnO ₂ | 34.5 Barium |
| .250 ZnO | | | 20.2 Zinc oxide |
| | | | 32.2 China clay |
| | | | 63.0 Flint |
| | | | 14.9 Tin oxide |

SERIES P.—Raw porcelain glaze at cone 9

| | | | Batch weights |
|-----------------------|-------------------------------------|-----------------------|-----------------------|
| 0.36 K ₂ O | | | 174.9 Feldspar |
| .23 ZnO | 0.54 Al ₂ O ₃ | 4.00 SiO ₂ | 30.0 Whiting |
| .35 CaO | | .10 SnO ₂ | 16.2 Zinc oxide |
| .06 BaO | | | 9.8 BaCO ₃ |
| | | | 38.7 China clay |
| | | | 78.0 Flint |
| | | | 14.9 SnO ₂ |

Substitutes Used for SnO_2 .—In the first number of each series 0.10 SnO_2 was used, and in the succeeding numbers the same amount by weight of the substitutes was used to replace the tin oxide. Some of these substitutes are so composed that it is not possible to use them by equivalents, and as they are all purchased by weight, that is the only practical method of comparison when price is considered.

- Glaze 1—Tin oxide marketed by Roessler & Hasslacher Chemical Co.
- Glaze 2—Terrar from Roessler & Hasslacher Chemical Co.
- Glaze 3—Zirconium oxide from A. D. Camp, Cleveland.
- Glaze 4—Zirconium oxide from Aluminum Alloys Co., Niagara Falls, N. Y.
- Glaze 5—Zirconium oxide (pure) from Pennsylvania Salt Co.
- Glaze 6—Fluorspar.
- Glaze 7—White antimony oxide.
- Glaze 8—Aluminum oxide (hydrated)
- Glaze 9—Kryolith, from Roessler & Hasslacher Chemical Co.
- Glaze 10—Leukonin, from Roessler & Hasslacher Chemical Co.
- Glaze 11—Stannolite, from Wenger's, Ltd., England.
- Glaze 12—Phosphorite, from Wenger's, Ltd., England.
- Glaze 13—Lithopone, from Harrison Bros., Philadelphia.

Data on Substitutes.—"Terrar" is an imported product largely used in the enamel iron industry before the war made it impossible to obtain it. It is probably composed largely of zirconium oxide and zirconium silicate. "Leukonin" is also used in enamel iron work, and is essentially sodium metantimonate. It is not recommended for general glaze purposes. "Stannolite" and "Phosphorite" are compounds whose composition is unknown. They are said to be used very extensively in England for opacifiers in place of tin oxide. "Lithopone" is a compound of 30 per cent zinc sulphide and 70 per cent barium sulphide. It is now being used very largely by the rubber manufacturers in place of zinc oxide.

Firing.—All glazes were made up in batch weights in grams, thoroughly ground in a ball mill, and applied to small grogged body tiles which had previously been fired to cone 9. Series "R," "F" and "T" were fired in a large test kiln to the indicated heats. Series "P" was fired in a large sanitary kiln requiring 120 hours for firing.

Results from Firings.—

SERIES R.

- R- 1—Semi-opaque. Milky white. Not well glossed
- R- 2—Less opaque than 1. Not so white.
- R- 3—Not quite so opaque as 2. Bubbled.
- R- 4—About the same as 2.
- R- 5—Similar to 3. Bubbled.
- R- 6—Clear glaze. Crazed.
- R- 7—Slight opacity. Full gloss.
- R- 8—Clear glaze.
- R- 9—Clear glaze. Badly crazed.
- R-10—Same opacity as 7.
- R-11—Same opacity as 7.
- R-12—Clear glaze. Crazed.
- R-13—Clear glaze. Not fully matured.

Tin oxide shows the best opacity in this series. Would require at least 0.15 equivalent for good opaque glaze. None of the substitutes offer much encouragement, although "terror" might show results if used in much larger amounts than is required of the tin oxide.

SERIES F

- F- 1—Semi-opaque enamel. Glossy.
- F- 2—Slightly more opaque than 2, but blistered.
- F- 3—Not quite so opaque as 1. Dull surface.
- F- 4—Less opaque than 3. More gloss.
- F- 5—Clear glaze. Full gloss.
- F- 6—Clear glaze. Full gloss.
- F- 7—Slight opacity. Full gloss.
- F- 8—Clear glaze. Full gloss.
- F- 9—Clear glaze. Full gloss. Crazed.
- F-10—Slight opacity. Less than 7. Full gloss.
- F-11—Slight opacity. Less than 7. Full gloss.
- F-12—Clear glaze. Glossy.
- F-13—Same as 11. Crazed.

Tin oxide is the best opacifier in this group. The commercial zirconium oxide in 2 is the next best. The pure zirconium oxide in 5 shows no opacity whatever. It is evident that this type of fritted glaze is not at all suited to use for opaque purposes. Glaze "R" and glaze "F" are about equal.

SERIES T

- T- 1—Good opaque enamel. Glossy.
- T- 2—Fair opaque enamel. Glossy. Not quite so white as 1.

- T- 3—Good white opaque. Beaded. Not quite so white as 1.
- T- 4—Fair opacity, but less than 2. Glossy.
- T- 5—Good white opaque. Not quite equal to 1.
- T- 6—Only slight opacity. Crazed.
- T- 7—Opaque white. Almost equal to 1 except that it is bubbled.
- T- 8—Fair opaque white. Mat surface.
- T- 9—Slightly more opacity than 6. Semi-glossy.
- T-10—Good opacity. Glossy. Not fully freed from bubbles.
- T-11—Semi-opaque. Glossy.
- T-12—Semi-opaque. Glossy.
- T-13—Semi-opaque. Slight gloss.

There are more opaque glazes in this series than in the first two. Zirconium oxide (pure) in 5 seems equal to tin oxide for opacity, but the glaze is not quite so white. Antimony oxide is equal to tin oxide for opacity but the glaze is not fully developed. Aluminium oxide produces a very good opaque mat glaze. Leukonin seems almost equal to tin oxide for opacity, color and gloss.

SERIES P

- P- 1—Good opaque white. Crawled some.
- P- 2—Semi-opaque white. Same as "T"-2.
- P- 3—Same opacity as 1. Not so white. Crawled.
- P- 4—Same as 2.
- P- 5—About the same as 3. Not quite so good as 1.
- P- 6—Almost a clear glaze.
- P- 7—Flocculent opaque white. Crawled.
- P- 8—Semi-opaque. Less than 2 and 4.
- P- 9—Clear glaze. Glossy.
- P-10—Slight opacity. Glossy.
- P-11—Semi-opaque; less so than 8.
- P-12—Slight opacity. Glossy.
- P-13—Slightly opaque, material in suspension.

Tin oxide still seems to be the best opacifier, although "terror" and zirconium oxide, especially the pure, seem to offer possibilities of being good substitutes. More material might be required for the same opacity as from tin oxide, but the other defects can no doubt be overcome.

General Conclusions

1. Zinc oxide is of great assistance in producing opacity with tin oxide and with the substitutes, as is shown in series "T" and "P."

2. Barium exerts a marked influence on opacity, as shown in a comparison of series "T" with series "P."

3. Zinc and barium oxide have more influence on opacity than the clay content.

4. A glaze of type "T," with both barium and zinc, is most favorable for opacity. This applies to tin oxide as well as the substitutes.

5. Where they can be used leukonin and antimony oxide are cheaper than tin oxide. Zirconium oxide is the best substitute for tin oxide if it can be procured at a sufficiently low price.

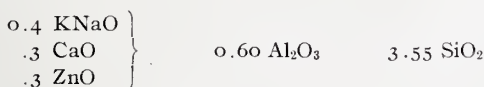
SOME DATA ON THE DEVELOPMENT OF TERRA COTTA GLAZES

By E. C. HILL

The study of Bristol glazes has received considerable attention in the past, and the extensive investigations made have covered the subject somewhat thoroughly. Bristol glaze mixtures are generally understood to be those containing feldspar, flint, clay, whiting and zinc oxide. The object of the work described herein was to study the effect of the addition to Bristol glaze mixtures of tin oxide, barium and magnesium carbonate, one or more of which are commonly used in the production of terra cotta glazes, and of strontium carbonate, not ordinarily used.

Part I

In the first part of the work, the additions were made to the eutectic mixture developed by Watts¹ in his study of Bristol glazes compounded on the eutectic basis. The molecular formula of this mixture is:



and is the eutectic of three eutectic mixtures as follows:

| | | | |
|------|--------------------------------------|-----------------------|----------------------------|
| KNaO | Al ₂ O ₃ | 6.4 SiO ₂ | feldspar and flint |
| ZnO | 0.318 Al ₂ O ₃ | 0.81 SiO ₂ | zinc oxide, clay and flint |
| CaO | .348 Al ₂ O ₃ | 2.49 SiO ₂ | whiting, clay and flint |

The glaze mixtures in this study were calculated from the molecular formulas. Canadian feldspar (molecular weight 557) was used. The clay mixture was composed of three parts English china clay and one part Kentucky ball clay (molecular weight for the clay taken as 258). The mixtures were weighed in 500-gram batches, ground with water for thirty minutes in laboratory jar mills, and sprayed on trials of a commercial terra cotta body

¹ *Trans. Am. Ceram. Soc.*, 18, 631 (1916).

and engobe. Four trials of each were made, two being fired in a terra cotta kiln at cone 7 and two at cone $5\frac{1}{2}$. The cone 7 trials were fired in three different kilns but the cone $5\frac{1}{2}$ trials were fired together in one kiln.

In addition to the sprayed trials, portions of the glaze mixtures were dried, ground in a mortar and molded into test cones. The cones were fired in a gas-fired laboratory test kiln and the order of deformation observed closely. The cones were set on plaques in series and also with equal molecular equivalents of SnO_2 , MgO , BaO and SrO . Four burns in all were made on the cones, and at least two burns were made on each mixture. Several cones of some of the mixtures were fired in each burn. The temperature of the kiln was rapidly increased to just below that required for the deformation of the cones, and as slowly as possible after the first mixtures began to deform.

Series A.—Tin Oxide

| | A | A1 | A2 | A3 | A4 | A5 |
|-------------------------------|------|------|------|------|------|------|
| K_2O | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| CaO | .30 | .30 | .30 | .30 | .30 | .30 |
| ZnO | .30 | .30 | .30 | .30 | .30 | .30 |
| SnO_2 | ... | .05 | .10 | .15 | .20 | .25 |
| Al_2O_3 | .60 | .60 | .60 | .60 | .60 | .60 |
| SiO_2 | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 | 3.55 |

The SnO_2 was not included in the RO of the formula. A is the eutectic glaze developed by Watts. In these burns it was a bright mat of creamish tint. The whiteness increases with the addition of SnO_2 to 0.10 equivalent (3.83 per cent tin oxide), but further additions increase the whiteness only slightly. The texture and sheen of A, A1 and A2 are about the same, but further additions of SnO_2 decrease the sheen of the mats. At cone $5\frac{1}{2}$, A5 was not well matured. All trials of A5 show small parting cracks, so that excessive amounts of SnO_2 may increase the crawling tendency of the glaze. However, more than 0.20 equivalent SnO_2 (7.40 per cent tin oxide in this series) is rarely used to increase the whiteness of glazes of this kind.

Cone Deformation.—A began to deform first and completed deformation at about the same time as standard cone 02, followed

by the balance of the series in order. Any addition of SnO_2 decreases the fusibility of A and the decrease is about in proportion to the amount of SnO_2 added.

Series B.—Magnesium Carbonate

| | A2 | B1 | B2 | B3 | B4 | B5 | B6 |
|-------------------------------|------|------|------|------|------|------|------|
| K_2O | 0.40 | 0.38 | 0.36 | 0.34 | 0.32 | 0.30 | 0.28 |
| CaO | .30 | .285 | .27 | .255 | .24 | .225 | .21 |
| ZnO | .30 | .285 | .27 | .255 | .24 | .225 | .21 |
| SnO_2 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MgO | ... | .05 | .10 | .15 | .20 | .25 | .30 |
| Al_2O_3 | .60 | .59 | .579 | .569 | .558 | .548 | .538 |
| SiO_2 | 3.55 | 3.47 | 3.39 | 3.32 | 3.24 | 3.16 | 3.09 |

Watts¹ determined the eutectic mixture of MgO , Al_2O_3 and SiO_2 to be $\text{MgO} \cdot 0.392 \text{Al}_2\text{O}_3 \cdot 2.00 \text{SiO}_2$, which deforms at cone 12. The addition of MgO to glaze A2 (which is the same as Watts' eutectic glaze, but contains 0.10 equivalent SnO_2 , not included in the RO) was made to conform to the eutectic mixture so that 0.392 Al_2O_3 and 2.00 SiO_2 were added for each equivalent of MgO . The addition was made by decreasing the molecular formula of A2 throughout by an amount equal to the addition of the equivalent MgO added, and adding the required amount of Al_2O_3 and SiO_2 to conform to the eutectic mixture. Thus, the formula of B1 (0.05 MgO) was obtained by multiplying the molecular equivalents of glaze A2 by the factor 0.95 and adding 0.05 MgO ; $0.05 \times 0.392 = 0.0196 \text{Al}_2\text{O}_3$ and $0.05 \times 2.0 = 0.10 \text{SiO}_2$. The MgO was introduced as the "heavy" magnesium carbonate.

The texture of the series is that of a bright mat. The sheen increases somewhat with increase of MgO to 0.20 equivalent, but further additions decrease it. At cone 5 $\frac{1}{2}$, B5 and B6 are immature. B3 and B4 have some fine parting cracks and B5 and B6 have crawled badly. On this account, glazes of this kind should not contain more than 0.20 equivalent MgO and preferably not more than 0.10 equivalent.

Cone Deformation.—A2 deforms first, followed by the rest of the series in order. Any addition of MgO makes the glaze more refractory, and the increase is about proportional to the amount

¹ *Trans. Am. Ceram. Soc.*, 19, 456 (1917).

of MgO added. Series B is more refractory than Series A. All cones of the A series are down before B₃ (0.15 MgO) deforms.

Series C.—Barium Carbonate

| | A2 | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|--------------------------------------|------|------|------|------|------|------|------|------|------|
| K ₂ O..... | 0.40 | 0.38 | 0.36 | 0.34 | 0.32 | 0.30 | 0.28 | 0.26 | 0.24 |
| CaO..... | .30 | .285 | .27 | .255 | .24 | .225 | .21 | .195 | .18 |
| ZnO..... | .30 | .285 | .27 | .255 | .24 | .225 | .21 | .195 | .18 |
| SnO ₂ | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| Al ₂ O ₃ | .60 | .592 | .583 | .575 | .566 | .558 | .549 | .541 | .532 |
| SiO ₂ | 3.55 | 3.57 | 3.60 | 3.62 | 3.64 | 3.66 | 3.69 | 3.71 | 3.73 |
| BaO..... | ... | .05 | .10 | .15 | .20 | .25 | .30 | .35 | .40 |

Watts¹ found two mixtures of BaO, Al₂O₃ and SiO₂ that deformed at about the same time, but before any of the others. The one selected as a deformation eutectic, because of its rapid deformation, was BaO·0.43Al₂O₃·4.01SiO₂, which deformed at cone 6. The method of making the additions of BaO were the same as that used for MgO in series B.

Series C gave good white mats. The sheen decreases only slightly with increase of BaO.

Cone Deformation.—A₂ deforms first, followed by the balance of the series in order. Any increase of BaO decreases the fusibility of A₂, and the decrease is about proportional to the amount of BaO added. Series C is much more refractory than series A or B. All the cones of B series go down before C₃ (0.15 equivalent BaO) deforms.

Series D.—Strontium Carbonate

| | A2 | D1 | D2 | D3 | D4 | D5 | D6 | D7 | D8 |
|--------------------------------------|------|------|------|------|------|------|------|------|------|
| K ₂ O..... | 0.40 | 0.38 | 0.36 | 0.34 | 0.32 | 0.30 | 0.28 | 0.26 | 0.24 |
| CaO..... | .30 | .285 | .27 | .255 | .24 | .225 | .21 | .195 | .18 |
| ZnO..... | .30 | .285 | .27 | .255 | .24 | .225 | .21 | .195 | .18 |
| SnO ₂ | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| SrO..... | ... | .05 | .10 | .15 | .20 | .25 | .30 | .35 | .40 |
| Al ₂ O ₃ | .60 | .57 | .54 | .51 | .48 | .45 | .42 | .39 | .36 |
| SiO ₂ | 3.55 | 3.37 | 3.20 | 3.02 | 2.84 | 2.66 | 2.49 | 2.31 | 2.13 |

Series D gave good white mats, the texture becoming more dull with increase of SrO. D₇ and D₈ are slightly immature at cone 7 and D₅ to D₈ are immature at cone 5¹/₂.

¹ *Trans. Am. Ceram. Soc.*, 19, 459.

Cone Deformation.—A2 deforms first, followed by the balance of series in order. Any increase of SrO decreased the fusibility of A2, and the decrease is about proportional to the amount of SrO added. This series is only slightly less fusible than the B series (MgO), but is considerably more fusible than the C series (BaO).

Series E and F.—Magnesium and Barium Carbonate

| | A2 | E1 | E2 | E3 | E4 | F1 | F2 | F3 | F4 | F5 |
|-------------------------------------|------|------|------|------|------|------|------|------|------|------|
| K ₂ O..... | 0.40 | 0.36 | 0.32 | 0.28 | 0.24 | 0.37 | 0.34 | 0.31 | 0.28 | 0.24 |
| CaO..... | .30 | .27 | .24 | .21 | .18 | .278 | .255 | .233 | .21 | .18 |
| ZnO..... | .30 | .27 | .24 | .21 | .18 | .278 | .255 | .233 | .21 | .18 |
| SnO ₂ | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MgO..... | ... | .05 | .10 | .15 | .20 | .025 | .05 | .075 | .10 | .133 |
| BaO..... | ... | .05 | .10 | .15 | .20 | .05 | .10 | .15 | .20 | .267 |
| Al ₂ O ₃ | .60 | .581 | .562 | .543 | .524 | .586 | .573 | .559 | .545 | .531 |
| SiO ₂ | 3.55 | 3.50 | 3.44 | 3.39 | 3.33 | 3.53 | 3.52 | 3.50 | 3.49 | 3.47 |

In the series E and F, MgO and BaO together are added to A2. In the former, they are added in equal equivalents and in the latter, two equivalents BaO to one MgO. The results are about what would be expected from series B and C. All are good mats, except E4 and F5, which are immature at cone 5^{1/2}. E4 has some parting cracks.

Cone Deformation.—A2 deforms first, followed by E1. F1 is next, then E2. F5 is last to deform.

Series G and H.—Clay and Flint Variations

| | F2 | G1 | G2 | G3 | G4 | H1 | H2 | H3 |
|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| K ₂ O..... | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 | 0.34 |
| CaO..... | .255 | .255 | .255 | .255 | .255 | .255 | .255 | .255 |
| ZnO..... | .255 | .255 | .255 | .255 | .255 | .255 | .255 | .255 |
| SnO ₂ | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MgO..... | .05 | .05 | .05 | .05 | .05 | .05 | .05 | .05 |
| BaO..... | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| Al ₂ O ₃ | .573 | .523 | .473 | .423 | .373 | .523 | .473 | .423 |
| SiO ₂ | 3.52 | 3.42 | 3.32 | 3.22 | 3.12 | 3.22 | 2.92 | 2.62 |
| Clay..... | 0.233 | 0.183 | 0.133 | 0.083 | 0.033 | 0.183 | 0.133 | 0.083 |
| Flint..... | 1.01 | 1.01 | 1.01 | 1.01 | 1.01 | .81 | .61 | .41 |

In series G, the clay is reduced by 0.05 equivalent in each member, starting with F2 (0.05 MgO·0.10BaO). In series H, the clay is reduced by 0.05 equivalent, in each member, starting with F2

and for each 0.05 equivalent of clay, 0.20 equivalent flint are taken from the flint content.

G₁ is a good mat. The gloss increases proportionately with decrease of clay. G₄ is a bright, glossy glaze. H₁ is a good mat. The sheen becomes duller with decrease of clay and flint. H₃ has a very dull texture, but is fully matured.

Cone Deformation.—G₄ (0.033 equivalent clay) is the first to deform, followed in order by G₃, G₂ and G₁. Decrease of clay increases the fusibility proportionately. H₃ (0.083 clay, 0.41 flint) deforms first, followed by H₂ and H₁ in order. Decrease of clay increases the fusibility proportionately, even with decreasing flint. Comparing the two series, G₄ and G₃ deform before H₃. H₂ deforms at about the same time as G₁. All deform before E₂.

Series I and J.—Clay and Flint Variations

| | F5 | I1 | I2 | I3 | I4 | I5 | J1 | J2 | J3 | J4 | J5 |
|------------------------------------|------|------|------|------|------|------|------|------|------|------|------|
| K ₂ O... | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 | 0.24 |
| CaO... | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 |
| ZnO... | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 | .18 |
| SnO ₂ ... | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| MgO... | .133 | .133 | .133 | .133 | .133 | .133 | .133 | .133 | .133 | .133 | .133 |
| BaO... | .267 | .267 | .267 | .267 | .267 | .267 | .267 | .267 | .267 | .267 | .267 |
| Al ₂ O ₃ ... | .53 | .48 | .43 | .38 | .33 | .28 | .48 | .43 | .38 | .33 | .28 |
| SiO ₂ ... | 3.47 | 3.37 | 3.27 | 3.17 | 3.07 | 2.97 | 3.17 | 2.97 | 2.77 | 2.57 | 2.37 |
| Clay... | .29 | .24 | .19 | .14 | .09 | .04 | .24 | .19 | .14 | .09 | .04 |
| Flint... | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.25 | 1.05 | .85 | .65 | .45 |

As in series G and H, the clay and flint are reduced. The reductions are made in F₅ (0.133MgO·0.267BaO). In series I, as in series G, any reduction of clay increases the gloss. I₁ is a good mat, I₄ and I₅ are bright. In series J, as in series H, the reduction of clay and flint together decreases the sheen of the mats. J₁ is a good mat, J₄ and J₅ are dull and have a curdled appearance.

Cone Deformation.—I₅ deforms first, followed by I₄, I₃ and so forth. J₅ deforms first in this series, followed by J₄, J₃, and so forth. The behavior of series I and J is similar to series G and H. From the results shown by E and F, we would expect

series G to be considerably more fusible than series I. Series G is more fusible on the high clay end of the series; but in the low clay glazes, series I is the more fusible. Thus when G₃ and G₄ were fired with I₄ and I₅, I₅ deformed first and I₄ and G₄ deformed close together. This may be due to the fact that the I series has a higher flint content.

Part II

The original outline of this study included only series A to J. The effect of the clay-flint variations led to the study of the effect on other RO, and to making the additions of SnO₂, MgO, BaO and SrO to a low-clay glaze instead of the one with 0.20 equivalent clay.

Series K and L.—Clay and Flint Variations

| | A2 | K1 | K2 | K3 | A | L1 | L2 | L3 |
|--------------------------------------|------|------|------|------|------|------|------|------|
| K ₂ O..... | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| CaO..... | .30 | .30 | .30 | .30 | .30 | .30 | .30 | .30 |
| ZnO..... | .30 | .30 | .30 | .30 | .30 | .30 | .30 | .30 |
| SnO ₂ | .10 | .10 | .10 | .10 | ... | ... | ... | ... |
| Al ₂ O ₃ | .60 | .55 | .50 | .45 | .60 | .55 | .50 | .45 |
| SiO ₂ | 3.55 | 3.45 | 3.35 | 3.25 | 3.55 | 3.45 | 3.35 | 3.25 |
| Clay..... | 0.20 | 0.15 | 0.10 | 0.05 | 0.20 | 0.15 | 0.10 | 0.05 |
| Flint..... | .75 | .75 | .75 | .75 | .75 | .75 | .75 | .75 |

In series K, the gloss increases from A₂, bright mat, to K₃, a bright, glossy glaze. In series L, the gloss increases from A, bright mat, to L₃, a bright glossy glaze. L₃ is transparent and shows the buff body of the trial. The opacity increases from L₃ to A.

Cone Deformation.—K₃ deforms first, followed in order by K₂, K₁ and A₂. K₃ deforms with cone 0₃ and deforms at least one cone before A₂. In the L series, L₃ deforms first at about cone 0₃, followed in order by L₂, L₁ and A. L₃ deforms at the same time as K₃, there being practically no difference in their deformation behavior. There is from one-half to one cone difference between L₃ and A. L₁ deforms before K₁ and A before A₂, but there is practically no difference between L₃ and K₃. K₁, K₃, L₁ and L₃ were prepared again for a check. The clay in the original mixtures was three parts English ball and one part

Kentucky ball. In the check glazes, as well as those that follow, Florida kaolin was used as the source of clay. In the check series, L₃ deformed before L₁ and K₃ before K₁.

Series M and N

| | M1 | M2 | N1 | N2 |
|--------------------------------------|------|------|------|------|
| K ₂ O..... | 0.30 | 0.30 | 0.50 | 0.50 |
| CaO..... | .35 | .35 | .25 | .25 |
| ZnO..... | .35 | .35 | .25 | .25 |
| Al ₂ O ₃ | .45 | .35 | .65 | .55 |
| SiO ₂ | 2.85 | 2.65 | 4.05 | 3.85 |
| Clay..... | 0.15 | 0.05 | 0.15 | 0.05 |
| Flint..... | .75 | .75 | .75 | .75 |

Series M and N were made in connection with the check glazes K₁, K₃, L₁ and L₃. M₁ is mat. M₂ is transparent and glossy. N₁ is a bright mat, N₂ is transparent and glossy.

Cone Deformation.—Series M and N were fired with L₁ and L₃. Three burns were made in which these cones were fired on the same plaque and the order of deformation closely observed. In every case L₃ deformed first. L₁, M₁, M₂ and N₂ deformed so nearly together that there is practically no difference in their order of deformation, and it is difficult to make any distinction between them. N₁ deforms very slowly and is considerably behind the others. All of these mixtures, except N₁, deformed before A.

Series O and P

| | L3 | O1 | O2 = K3 | O3 | O4 | P1 | P2 | P3 | P4 |
|--------------------------------------|------|------|---------|------|------|------|------|------|------|
| K ₂ O..... | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.38 | 0.36 | 0.34 | 0.32 |
| CaO..... | .30 | .30 | .30 | .30 | .30 | .285 | .27 | .255 | .24 |
| ZnO..... | .30 | .30 | .30 | .30 | .30 | .285 | .27 | .255 | .24 |
| SnO ₂ | ... | .05 | .10 | .15 | .20 | .10 | .10 | .10 | .10 |
| MgO..... | ... | ... | ... | ... | ... | .05 | .10 | .15 | .20 |
| Al ₂ O ₃ | .45 | .45 | .45 | .45 | .45 | .45 | .45 | .45 | .45 |
| SiO ₂ | 3.25 | 3.25 | 3.25 | 3.25 | 3.25 | 3.13 | 3.01 | 2.89 | 2.77 |

In series O, SnO₂ is added to mixture L₃. In series P, MgO is added to K₃, the same mixture as L₃ but with 0.10 equivalent SnO₂. "Light" magnesium carbonate was used. At cone 7, series O is glossy. At cone 5¹/₂, it is a bright mat. There is little difference in the gloss or texture of these glazes, although

O₄ has slightly less gloss than the others. Series P is bright at both cone 5¹/₂ and 7. The entire surface of all the trials in this series are badly crawled or parted, which must be attributed to the use of the "light" magnesium carbonate, as none of the glazes in the other series crawled like these.

Cone Deformation.—L₃, O₁, O₂ and O₃ deform at practically the same time, with O₄ only slightly behind. SnO₂ can be added to the low-clay glaze without decreasing the fusibility up to and including 0.15 equivalent SnO₂. In series P, any addition of MgO to K₃ makes the mixture less fusible. All of the O series are deformed before P₂.

Series Q and R

| | K3 | Q1 | Q2 | Q3 | Q4 | R1 | R2 | R3 | R4 |
|--------------------------------------|------|------|------|------|------|------|------|------|------|
| K ₂ O..... | 0.40 | 0.38 | 0.36 | 0.34 | 0.32 | 0.38 | 0.36 | 0.34 | 0.32 |
| CaO..... | .30 | .285 | .27 | .255 | .24 | .285 | .27 | .255 | .24 |
| ZnO..... | .30 | .285 | .27 | .255 | .24 | .285 | .27 | .255 | .24 |
| SnO ₂ | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 | .10 |
| BaO..... | ... | .05 | .10 | .15 | .20 | ... | ... | ... | ... |
| SrO..... | ... | ... | ... | ... | ... | .05 | .10 | .15 | .20 |
| Al ₂ O ₃ | .45 | .45 | .45 | .45 | .45 | .45 | .45 | .45 | .45 |
| SiO ₂ | 3.25 | 3.13 | 3.01 | 2.89 | 2.77 | 3.13 | 3.01 | 2.89 | 2.77 |

In series Q, BaO is added to K₃. In series R, SrO is added to K₃. Series Q are all good white mats, with the sheen decreasing slightly with increase of BaO. Series R is quite similar in color and texture to series Q, but the series has more sheen than Q, the sheen decreasing slightly with increase of SrO.

Cone Deformation.—In series Q, additions of BaO decrease the fusibility more than additions of either MgO or SrO. P₁ and P₂ are completely deformed before Q₁ starts to deform. In series R, additions of SrO decrease the fusibility more than MgO, but less than BaO.

Summary

Bristol Glaze Mixtures.—The method of studying Bristol glaze mixtures used by Watts,¹ compounding the mixtures on the eutectic basis, is a convenient means of covering a considerable range of composition, and is no doubt more scientific than the usual method of studying glazes by direct variation of the molecu-

¹ *Trans. Am. Ceram. Soc.*, 18, p. 631.

lar formula. However, in these complex mixtures, it is doubtful whether the eutectic method can be relied upon to produce the most fusible glaze.

The mixture developed by Watts is no doubt the best that can be produced from these mixtures as a bright, opaque, white glaze for stoneware;¹ it is not the most fusible mixture of the components. In series L of this study, it was found that this glaze could be made considerably more fusible by the reduction of clay. The low-clay glaze would not be satisfactory for stoneware, as it is transparent; but as a basis for introducing other materials used in the production of terra cotta glazes, it gave much better results than the eutectic glaze developed by Watts. Watts' study covered thoroughly the ground included between the eutectic mixtures used as the extremes of his investigation, and the data obtained are of great value. From the standpoint of the development of glazes for terra cotta there remains a considerable field of investigation open for the study of these mixtures. The area of fusible low-clay glazes was not touched in the eutectic investigation by Watts, since the mixtures with 0.10 equivalent of clay or less, contained 0.7 equivalent or more of feldspar. In the eutectic area the mixtures did not contain much more than 0.75 equivalent free SiO_2 . It is quite likely that in the low-clay glazes, a further increase of SiO_2 would produce more fusible glazes.

Regarding the effect of clay on the Bristol glaze mixtures covered by series L, M and N in this study, it will be noted that in series M ($\text{RO} = 0.30\text{K}_2\text{O} \cdot 0.35\text{CaO} \cdot 0.35\text{ZnO}$) there was practically no difference in the fusibility of the mixture whether the clay was 0.05 or 0.15 equivalent. In a study by Purdy,² with the $\text{RO} = 0.20\text{K}_2\text{O} \cdot 0.40\text{CaO} \cdot 0.40\text{ZnO}$, mixtures with 0.16 and 0.20 equivalent were more fusible than any with less clay. In series L of this study, $0.40\text{K}_2\text{O} \cdot 0.30\text{CaO} \cdot 0.30\text{ZnO}$, L₃, 0.05 equivalent clay gave a more fusible mixture than any of the mixtures in the study. This mixture was somewhat more fusible than the same one with 0.15 equivalent clay, although the latter deformed as soon as any

¹ *Trans. Am. Ceram. Soc.* 19, p. 301.

² *Ibid.*, 5, p. 159.

in series M and N. In series N, $0.50\text{K}_2\text{O}\cdot 0.25\text{CaO}\cdot 0.25\text{ZnO}$, N_2 0.05 equivalent clay, deformed at about the same time as the others, except L_3 , but N_1 , 0.15 equivalent clay, was more refractory than any in series M and L.

In these series, it is shown that as the feldspar is increased, additions of clay make the mixture less fusible, until in series N, 0.50 equivalent feldspar, there is a great difference in the fusibility when the mixtures contain 0.05 and 0.15 equivalent clay. In a study made by the writer¹ it was shown that in high-zinc Bristol glaze mixtures, any increase of clay decreased the fusibility of the mixtures considerably. It is evident then that clay increases the fusibility of the mixtures only when there is a considerable amount of CaO present, and in mixtures similar to those in this study, the CaO must be 0.40 equivalent or more. CaO is the only component of a Bristol glaze that reacts readily with clay to form fusible mixtures. The results of the L, M and N series point strongly to the conclusion that mixtures similar to L_3 , with equal amounts of CaO and ZnO and low clay, will be found to be more fusible than any high CaO high-clay mixtures possible with these components. A certain amount of CaO is essential to this type of glaze, however, since it cannot be replaced readily by any other components without decreasing the fusibility of the glaze.

Terra Cotta Glaze Mixtures.—The addition of SnO_2 did not affect the glaze to a great extent. Added to the high-clay glaze, it decreased the fusibility of the mixture somewhat, but additions up to 0.15 equivalent gave a good white color. The high-clay glaze with 0.25 equivalent SnO_2 showed some parting cracks.

MgO decreased the fusibility of both the high- and low-clay glazes. We would expect that MgO, in small amounts at least, would lower the deformation point as it is considered an active flux. Riddle² found it to be a much more active flux in a porcelain body than CaO; 0.20 equivalent MgO from "heavy" magnesium carbonate in the high-clay glaze showed parting cracks in the glaze surface.

¹ *Trans. Am. Ceram. Soc.*, 18, p. 513.

² *J. Am. Ceram. Soc.*, 621 (1918).

Any addition of MgO from "light" magnesium carbonate caused crawling over the entire surface of the trial. The MgO series was more fusible than either the BaO or SrO series. MgO increased the gloss somewhat in the high-clay glazes and produced bright glazes throughout in the low-clay series.

SrO decreased the fusibility of the glazes in this study. The glazes had a good mat texture. It might be used to advantage to replace BaO wholly or in part in terra cotta glazes, since it gives a somewhat more fusible glaze, were it not for its high cost. The SrO series was more refractory than the MgO series.

BaO produced the least fusible glazes of the entire study. Any addition of BaO made the glaze considerably less fusible with each addition. The BaO series had a good mat surface, the surface growing duller with increase of BaO.

The order of deformation of glazes containing equal molecular equivalents of each was SnO_2 , MgO, SrO, BaO in both the high- and low-clay glaze. None of these, even in small amounts, produced a more fusible mixture. Seger,¹ discussing the control of fusibility of glazes, states that the fusibility may be increased by making the RO more complex, and that the glaze can be made more fusible by replacing lime or magnesia with lime and magnesia. This rule did not hold true in this study. The smallest amounts of any of the additions did not increase the fusibility; the addition of SnO_2 , MgO and BaO at the same time in small amounts decreases the fusibility. We know that the addition of ZnO to cone 4 mixture, $0.30\text{K}_2\text{O} \cdot 0.70\text{CaO} \cdot 0.50\text{Al}_2\text{O}_3 \cdot 4.00\text{SiO}_2$, increases the fusibility. It is likely that if a Bristol glaze mixture were overloaded with either CaO or ZnO, the addition of MgO, or possibly BaO or SrO, would increase the fusibility. But if the CaO and ZnO equivalent are present in the proportion to form a fusible glaze, it does not seem likely that the fusibility will be increased by the addition of any of the components used in this study.

The glazes in series O, P, Q and R are much more fusible than the corresponding glazes in series A, B, C and D. In the latter, the clay content is 0.20 to 0.25 equivalent; in the former, it is 0.05 equivalent. Since the addition of SnO_2 , MgO, BaO and SrO

¹ Seger's "Collected Writings," Vol. II, p. 572.

to the low-clay glaze gave much more fusible mixtures than the same additions to the high-clay glaze we may state that neither SnO_2 , MgO , BaO or SrO reacts readily with clay to form fusible mixtures. Combining this with the observations made regarding Bristol glaze mixtures, that neither feldspar nor zinc reacts readily with clay, we may state in mixtures containing all of these, in whatever amounts or combinations, the addition of clay will result in a less fusible glaze unless there is a considerable amount of CaO present. In this respect then, the behavior of CaO is entirely different from any RO elements ordinarily used in this type of glaze.

None of the trials of any of the mixtures in this study were crazed when drawn from the kiln. Crazing might develop in some of these mixtures on weathering the trials. None of the glazes developed a pink color,¹ which might occur under certain firing conditions, in glazes containing SnO_2 and CaO . None of the glazes were blistered.² Variations in the firing temperature, in the rate of firing, or in the kiln atmosphere, might result in the appearance of pink discoloration or blistering in some of these mixtures.

DEPARTMENT OF CERAMICS
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March, 1919

¹ *Trans. Am. Ceram. Soc.*, **18**, p. 396.

² *Ibid.*, **18**, p. 398.

THE IMPORTANCE OF ANALYSIS IN PURCHASING RAW MATERIALS FOR THE GLASS INDUSTRY

BY ALEXANDER SILVERMAN

The purpose of this paper is to bring to the attention of glass manufacturers the variation in composition of raw materials employed in the batch. It is presented to encourage constancy and thus permit, as nearly as possible, of the manufacture of a uniformly good product. Two raw materials may both be good but may differ in composition. Substitution of one for the other may spoil a glass unless proper correction is made for the difference in composition of the new material.

To obtain uniform results it is necessary not only to know the temperature of the furnace, duration of the melt, and so forth, but to keep informed as to the composition, form and size of raw materials and cullet. The technically trained man realizes these important facts, so the glass manufacturer should rely on his judgment in such matters. No new material should be substituted for one already giving satisfaction until the chemist decides that it can be introduced and that it will answer the purpose for which it is intended. In many cases a cheaper material can be utilized but unless the proper corrections are made in the batch the experiment may prove rather costly in the end.

The variations in composition cited in the following tables are not to be interpreted as a criticism of manufacturers of raw materials. Most of the materials are desirable for specific purposes, but there must not be a promiscuous substitution of one for the other.

The writer is indebted to the many manufacturers and dealers who were kind enough to submit analyses of their products. Letters were sent to all manufacturers known to the writer and the tables used in this article were, with but a few exceptions, compiled from data received.

Sand

Table 1, on composition of sands for glass-making, is condensed from Dralle.¹ Changes have been made in some of the limits so as to include American sands whose analyses were available.

¹ R. Dralle, *Die Glasfabrikation*, I, 141-145 (1911).

TABLE 1.—GENERAL COMPOSITION OF GLASS SANDS

| | The finer or so-called "quartz" sands Per cent | Plate glass sands Per cent | Window glass sands Per cent | Sands for chemical glassware Per cent |
|-----------------------------------|--|----------------------------------|-----------------------------------|---|
| SiO ₂ ... | 99.57-99.915 | 98-99.70 | 91.50-99.30 | 87.10-99.9 |
| Fe ₂ O ₃ .. | 0.0019-0.02 | 0.03-1.9 | 0.1-0.89 | 0.02-0.05 |
| Mn ₃ O ₄ | 0-0.02 | 0-0.015 | 0-0.064 | ..... |
| Al ₂ O ₃ .. | 0-0.17 | 0.04-2.13 | 0-4.90 | 0.02-7.41 |
| CaO... | 0-0.037 | 0-0.12 | 0-0.34 | 0-0.34 |
| MgO.. | 0-0.24 | 0-0.10 | 0-0.40 | 0-0.60 |
| Na ₂ O+ | | | | |
| K ₂ O | 0-0.042 | 0-0.17 | 0-0.10 | 0-3.49 |
| Ignition | | | | |
| loss. | 0-0.103 | 0-0.32 | 0-0.92 | 0-3.74 |

The next table (2) shows six sands¹ whose composition is so nearly uniform as to impel one to choose any one of the six.

TABLE 2.—CHEMICAL ANALYSIS OF HIGH-GRADE SANDS

| | 1 Per cent | 2 Per cent | 3 Per cent | 4 Per cent | 5 Per cent | 6 Per cent |
|--------------------------------------|---------------|---------------|---------------|---------------|---------------|---------------|
| SiO ₂ | 99.48 | 99.58 | 99.00 | 99.65 | 99.33 | 99.03 |
| Al ₂ O ₃ | 0.16 | 0.12 | 0.30 | 0.11 | 0.16 | 0.23 |
| Fe ₂ O ₃ | .02 | .02 | .03 | .02 | .02 | .02 |
| CaO..... | .11 | .13 | .15 | .12 | .15 | .21 |
| MgO..... | .05 | Trace | .00 | Trace | .11 | .05 |
| Ignition loss..... | .13 | .17 | .21 | .23 | .20 | .35 |

A glance at table 3 will, however, reveal a difference in the grain size of the six sands which is also an important factor.

It is well to consider both the chemical and the mechanical analysis. The form of the sand grains might be taken into account, so the magnifying glass also functions at times.

TABLE 3.—MECHANICAL ANALYSIS OF HIGH-GRADE GLASS SANDS

| Sample number | >1.0 mm. Per cent | >0.5 mm. and <1.0 mm. Per cent | >0.2 mm. and <0.5 mm. Per cent | >0.1 mm. and <0.2 mm. Per cent | >0.01 mm. and <0.1 mm. Per cent | <0.01 mm. Per cent | Total sand grade ² >0.1 mm. Per cent |
|------------------|----------------------|---|---|---|--|-----------------------|--|
| 1..... | 0.5 | 21.6 | 75.6 | 1.3 | 0.3 | 0.7 | 99.0 |
| 2..... | 0.0 | 6.1 | 88.4 | 5.1 | .2 | .2 | 99.6 |
| 3..... | .0 | 0.0 | 76.6 | 21.3 | .3 | 1.8 | 97.9 |
| 4..... | .0 | 1.5 | 97.1 | 0.8 | .2 | 0.4 | 99.4 |
| 5..... | 1.6 | 11.2 | 85.7 | .4 | .1 | 1.0 | 98.9 |
| 6...A few grains | | 2.7 | 90.1 | 6.1 | .5 | 0.6 | 98.9 |

¹ G. P. H. Boswell, "Notes on American High-Grade Glass Sands," *J. Soc. Glass Tech.*, 1, 147 (1917).

² Amount indicated in this column passed through a 16-mesh sieve and was retained by a 150-mesh sieve (Tyler standard).

The composition of sands, and other materials which follow, for specific purposes, has been discussed in the literature so it would seem unnecessary to repeat specifications here.

Soda Ash

By assembling the analyses of various brands of 58 per cent dense soda ash for sale in the United States the following limits (table 4) were obtained. To permit comparison an analysis of 48 per cent ash is also included.

TABLE 4.—COMPOSITION OF SODA ASH

| | 48 percent soda ash Per cent | 58 percent soda ash Per cent |
|--------------------------------|------------------------------------|------------------------------------|
| Na_2CO_3 | 83.055 | 99.05-99.52 |
| NaCl | 11.992 | 0.24-1.10 |
| Na_2SO_4 | 4.698 | .055-1.104 |
| Fe_2O_3 | 0.016 | 0-0.02 |
| Al_2O_3 | | 0-0.002 |
| CaCO_3 | .191 | 0-0.10 |
| MgCO_3 | .032 | 0-0.06 |
| SiO_2 | .016 | 0-0.003 |
| Insoluble matter..... | .... | 0-0.05 |

High sulphate and chloride content might prove objectionable for the manufacture of some glasses and not at all serious for others. The density of the ash is an important factor.

Pearl Ash

The next table (5) shows the composition of pearl ashes.

TABLE 5.—COMPOSITION OF PEARL ASH

| | Stassfurt 96-98 per cent Per cent | Stassfurt 98-100 per cent Per cent | From plant ashes Per cent | Refined beet sugar potash Per cent |
|--------------------------------|---|--|---------------------------------|--|
| K_2CO_3 | 97.15 | 99.45 | 40-75 | 90-95 |
| Na_2CO_3 | 0.07 | 0.05 | 3-6 | 3-5 |
| KCl | 1.25 | .06 | 1-10 | 1-3 |
| K_2SO_4 | ... | .02 | 15-30 | 1-3 |
| Water insoluble.. | 0.06 | ... | 2-4 | ... |
| H_2O | .31 | 0.40 | 4-10 | ... |

The writer has communicated with various American manufacturers during the past year and submits the following analyses (table 6) which were received:

TABLE 6.—COMPOSITION OF AMERICAN PEARL ASH

| | 1 Per cent | 2 Per cent |
|----------------------|---------------|---------------|
| K_2CO_3 | 80.50 | 83.90 |
| Na_2CO_3 | 0.36 | ... |
| KCl..... | 2.54 | 4.20 |
| K_2SO_4 | 0.09 | 2.60 |
| Water insoluble..... | .01 | 0.25 |
| H_2O | 16.50 | 9.05 |

When this paper was read at the Chicago meeting of the American Ceramic Society last September, a number of members present stated that the analyses submitted (table 6) did not include the better grades of American pearl ash. The writer has since written to manufacturers mentioned in the discussion and ascertained that while they manufactured high-grade material during the war, it is not available at present (October, 1919).

What has been said regarding sulphates and chlorides under soda ash also applies to pearl ash.

Salt Cake

Variations in the composition of salt cake are evident from the following (table 7) limits, taken from nine analyses received:

TABLE 7.—COMPOSITION OF SALT CAKE

| | Per cent |
|------------------------|--------------|
| Na_2SO_4 | 89.12-98.00 |
| NaCl..... | 0.62- 5.25 |
| H_2SO_4 | .20- 1.66 |
| Al_2O_3 | 0-0.27 |
| Fe_2O_3 | Trace 0-0.21 |
| CaO..... | 0-0.48 |
| MgO..... | 0-0.16 |
| Insoluble residue..... | Trace-0.77 |
| Water..... | 0-3.00 |

The desirability of reporting Fe_2O_3 and Al_2O_3 separately should be brought to the attention of manufacturers, as the iron content, especially, should be known.

¹ Three manufacturers reported Fe_2O_3 and Al_2O_3 together.

Niter

Fifteen analyses were submitted by dealers in niter. The limits are shown in table 8. For comparison the composition of double-refined niter is also given.

TABLE 8.—COMPOSITION OF NITER ON AMERICAN MARKET

| | Standard 15 samples Per cent | Double refined ² Per cent |
|---|------------------------------------|--|
| NaNO ₃ | 94.12-99.75 | 99.746-99.75 |
| NaCl..... | 0.02- 2.50 | 0.02 |
| MgCl ₂ | .00- 0.289 | .005 |
| Na ₂ SO ₄ | .00- 1.06 | ..... |
| Na ₂ B ₄ O ₇ | .00- 0.147 | ..... |
| Moisture..... | .00- 3.32 | 0-0.22 |
| Insoluble matter..... | .00- 0.35 | 0.003 |
| B ₂ O ₃ | .006 ¹ | .006 |
| CaO..... | .06 ¹ | ..... |
| KNO ₃ | .00- 3.9 | ..... |
| KClO ₃ | .00- 0.69 | ..... |
| NaIO ₃ | .01 ¹ | ..... |
| CaSO ₄ | .102 ¹ | ..... |
| MgSO ₄ | .219 | ..... |

¹ 1 analysis.

² 2 analyses.

Limestones and Limes

Analyses of twenty high-calcium American limestones are shown in table 9.

TABLE 9.—HIGH-CALCIUM LIMESTONES
Twenty analyses

| | Per cent |
|--|-------------|
| CaCO ₃ | 96.15-99.40 |
| MgCO ₃ | 0.11- 4.00 |
| Fe ₂ O ₃ | .12- 0.44 |
| Al ₂ O ₃ | Trace- 0.52 |
| Fe ₂ O ₃ + Al ₂ O ₃ ¹ | 0.25- 0.84 |
| SiO ₂ | .20- 2.12 |
| SO ₃ | .00- 0.18 |

Limits for seven dolomitic limestones are shown in table 10.

¹ Reported together in five samples; in remaining analyses they were reported separately.

TABLE 10.—DOLOMITIC LIMESTONES
Seven analyses

| | Per cent |
|---|---------------|
| CaCO ₃ | 53.80-59.16 |
| MgCO ₃ | 39.50-45.47 |
| Fe ₂ O ₃ ¹ | 0.38 and 0.23 |
| Al ₂ O ₃ ¹ | .20 and 0.28 |
| Fe ₂ O ₃ + Al ₂ O ₃ | .005- to 0.58 |
| SiO ₂ | .10- to 0.69 |
| Organic matter ¹ | .21 and 0.94 |

¹ Reported in only two analyses.

Burnt Lime.—Table 11 contains the limits given in analyses of ten high-calcium burnt limestones.

TABLE 11.—BURNT LIME (HIGH-CALCIUM)
10 Samples

| | Per cent |
|---|--------------|
| CaO..... | 89.20-98.05 |
| MgO..... | 0.10- 2.00 |
| Fe ₂ O ₃ + Al ₂ O ₃ | .23- 0.94 |
| SiO ₂ | .40- 2.30 |
| SO ₃ ¹ | .10 and 0.18 |

¹ Reported for two samples only.

The range for seven burnt dolomitic limestones is indicated in table 12.

TABLE 12.—BURNT LIME (HIGH-MAGNESIA)
7 Samples

| | Per cent |
|---|-------------|
| CaO..... | 55.62-60.02 |
| MgO..... | 39.50-41.67 |
| Fe ₂ O ₃ + Al ₂ O ₃ | 0.16- 0.88 |
| SiO ₂ | .05- 1.34 |
| SO ₃ ¹ | 0.90 |

¹ Reported for one sample only.

Hydrated Lime.—For six high-calcium hydrated limes table 13 shows the limits.

TABLE 13.—HYDRATED LIME (HIGH-CALCIUM)
6 Samples

| | Per cent |
|---|-------------|
| Ca(OH) ₂ | 92.50-98.54 |
| MgO..... | 0.12- 3.50 |
| Fe ₂ O ₃ + Al ₂ O ₃ | .21- 1.00 |
| SiO ₂ | .07- 2.00 |
| SO ₃ ¹..... | ..... |

¹ Reported in one sample only.

In some samples only 60 per cent of the material passed through a 100-mesh sieve. In one sample 99.34 per cent passed through a 100-mesh sieve; 98.48 per cent through a 200-mesh sieve.

Four hydrated dolomitic limes varied according to table 14.

TABLE 14.—HYDRATED LIME (HIGH-MAGNESIA)

4 Samples

| | Per cent |
|---|-------------|
| CaO..... | 47.08-50.47 |
| MgO..... | 32.04-40.73 |
| Fe ₂ O ₃ + Al ₂ O ₃ | 0.20- 0.51 |
| SiO ₂ | .08- 1.17 |
| Combined H ₂ O..... | 16.52-17.44 |
| CO ₂ | 0.69- 1.96 |

Manganese Dioxide

The extreme variation in composition of manganese dioxide is shown in the limits given (table 15) for six samples.

TABLE 15.—MANGANESE DIOXIDE

6 Samples

| | Per cent |
|---|---------------|
| MnO ₂ | 70.00-86.25 |
| MnO ¹ | 0.47 |
| Fe ₂ O ₃ | 0.25- 4.00 |
| SiO ₂ | .52- 3.85 |
| CuO ² | 0.01 and 0.03 |
| NiO ¹ | .30 |
| Al ₂ O ₃ ¹ | 1.74 |
| CaO ¹ | 1.73 |
| MgO ¹ | .20 |
| BaO ¹ | 1.54 |
| K ₂ O + Na ₂ O ¹ | 0.22 |
| CO ₂ ¹ | .63 |
| S ¹ | .23 |
| P ₂ O ₅ ¹ | .32 |
| H ₂ O..... | 1.85-13.33 |

¹ Reported for one sample only.

² Reported in two analyses.

Manganese dioxide may be purchased in any form from the finest powder to pea size. The color produced, or in other words, the decolorizing effect, depends on size and form as well as composition.

Talc

Four talc analyses showed variations within the following limits:

TABLE 16.—TALC
4 Samples

| | Per cent |
|---|-------------|
| SiO ₂ | 52.02-63.40 |
| MgO..... | 27.83-33.50 |
| CaO..... | 0.00- 6.01 |
| Fe ₂ O ₃ + Al ₂ O ₃ | .20- 2.18 |
| H ₂ O..... | 2.50- 4.44 |

A fifth analysis submitted showed no magnesia but 28 per cent Al₂O₃. Something would be likely to happen in a glass if an alumina-bearing mineral were substituted for a magnesia-bearing one simply as "talc" for "talc."

Feldspar

Feldspar variations are apt to be noticed quickly because of the use of this material in opal and alabaster glass manufacture. Eight samples from different localities varied as indicated in table 17. As alumina and potash are some of the factors which

TABLE 17.—COMPOSITION OF FELDSPAR
8 Samples

| | Per cent |
|--------------------------------------|-------------|
| SiO ₂ | 65.00-71.75 |
| Al ₂ O ₃ | 16.70-21.15 |
| K ₂ O..... | 8.19-10.60 |
| Na ₂ O..... | 1.10- 8.35 |
| Fe ₂ O ₃ | Trace- 0.40 |
| CaO..... | 0.12- 0.56 |
| MgO..... | .00- 0.15 |
| Ignition loss..... | .05- 9.35 |

govern the color in white glasses one should never buy a new brand of feldspar without making the necessary corrections in the batch.

Conclusions

Analyses of many other materials might be added. Four samples of fluorspar vary from 93 to 98 per cent in CaF₂; also

in their SiO_2 and CaCO_3 content. It would seem from the evidence already furnished unnecessary to burden the reader with more facts.

Raw materials do vary in composition. One may be able to save money by substituting a cheaper material and doing so advisedly. One is likely to lose money by substituting it pound for pound when the composition of the new material varies considerably from that of the substance formerly employed.

In this age, where economy is such an important factor in industry, every saving in cost counts. When a new material is offered, ask for a sample and an analysis. Submit these to your chemist and have him advise you concerning the desirability of making a change. If you purchase the new material have the chemist check the composition from time to time.

Buy on analysis and see that corrections are made in your glass to keep it uniform. Uninterrupted operation and a uniformly good product should result.

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NOTES ON SHEET AND PLATE GLASS MANUFACTURE

BY EDGAR H. BOSTOCK

The difficulty incident to contributing a paper to the Glass Division of the American Ceramic Society is that practically no technical work was done in glass in this country until very recently indeed; and of necessity all its developments have been commercial, or, more exactly, of the "get things done" method. As the growing needs of our country called for certain glass, we have filled the most obvious and profitable of these needs and have gone on importing glasses more difficult to make.

Even in those industries that we have established, a wealth of raw materials has lured us into wasteful methods and always into quantity and not quality production. It would seem that with the ideal fuel conditions that prevail with us, the best of sands and easy access to alkali productions, with the undoubted inventive genius among our engineers and adaptability of our labor, that we should now be able to make great progress in the production of better goods than we have heretofore produced. Particularly is this the opportune time as news is coming from Europe of the scarcity of labor and raw material over there, forcing up prices and making it possible for us to enter other lines of manufacture before this closed to us.

The writer's life and training has brought him into contact with the manufacture of flat glassware more particularly; and while I am not sure that this differs very much from other branches, still it is true that the chemist and physicist are almost unknown there. The progress made has been almost entirely the work of factory-trained men, and it is only within the last decade that the recently formed large combinations have made a start in the employment of search and research men.

The Sheet Window Glass Industry

The production of sheet window glass is very typical of the entire tale of American production and its future developments. Es-

tablished as a definite industry in the early 1800's according to the best practice of the times, for a century it was a wandering industry following cheap fuel, first the wood of New Jersey and the New York lake regions, then the bituminous coals of Pennsylvania and Pittsburgh, and, in the years succeeding the 80's, the natural gas of Ohio, Pennsylvania, West Virginia, latterly Kansas and Oklahoma. This rapid changing of location did not give time for developments of basic worth, and, with the exception of the adoption of the Belgian tank system of melting in 1888, no changes making for progress took place.

In 1894, John Lubbers, in New Kensington, Pennsylvania, was experimenting in the mechanical handling of cylinders and sheets in the flattening oven, and then conceived the idea of producing sheet glass mechanically. This process was based upon reproducing the methods employed by the hand blower mechanically. Many years and many millions of dollars were spent upon this process before it was commercially a success; but, as it eliminates the cost of highly skilled labor, it is now a great financial success and the process is used here and abroad.

The thought of all those who have studied the problem of sheet glass production always reverts to the drawing or producing of sheets directly from the molten mass without the intervention of any blowing or other process, and a great deal of work has been done and many patents granted and tried. Up to date the most successful would seem to be the Owens Company development of the Colburn process, which is producing glass in quantity and recently in fair quality.

The point to be overcome (other than the production of quality) is the elimination of "waves" in the glass due to it not being perfectly homogenous in the cylinder drawing processes, caused by the strain placed in glass when turned from cylindrical to sheet form, and in the Colburn process largely to the strain marks made when the sheet is turned from vertical to horizontal motion. Extrusion rather than drawing and direct production without turns would seem to be points of attack that promise results if persisted in.

The window glass factories seem to require very little help from the chemist, for with natural gas and excellent materials the writer

has seen glass melted in quality beyond compare. Perhaps they have not found or cared to use the ideal decolorants, and therefore, turn out glass of numerous green, yellowish and bluish tints due to slight impurities in the sands used.

There were, of course, certain specialties in sheet glass imported that recently we have had to produce, and thin, dry plate glass, microscopic slides and covers and similar thin goods are successfully made.

Fluted glass, so largely used in reflected lighting, is being made superior to the usual foreign article. This was flattened in Belgium in kilns heated with artificial gas, which would occasionally deposit a small film of "sulphur" upon the plastic sheet, invisible until the sheet was silvered when it detracted from the reflective value. Our glass flattened by natural gas, whose "sulphur" content seems nil, has a preferable surface.

One problem allied with sheet production so far seems to have escaped us—the making of colored sheet glass successfully. This is a complicated problem, for the chemist's help in furnishing formulas for the making of any and all colors does not entirely solve it. Due to the reheating in flattening a cylinder to a sheet, some queer problems in heat treatment are presented, especially in ruby glasses; and again when these colors are "flashed" or coated upon crystal glass, we have the problem of having the color coat and the body with about the same coefficient of expansion, so that both in working and in use they may stand temperature changes. Moreover, the manual difficulties under the conditions of producing sheets of even thickness are such that we have not yet solved them. At least two firms are bravely attacking these problems.

The Plate Glass Industry

The plate glass industry has been able to make a better showing of progress than most branches of the industry. Of necessity it is organized into large units with large companies controlling them, who have worked for progress. When selected and graded properly, their product leads the world. For glazing purposes it is superior, for melted from a little more refractory material, its

surface is harder and more resistant to abrasion by wind-blown particles or cleaning.

When the need arose our supply of optically perfect plate for instrument work proved ample.

Possibilities of Development

Possibly our greatest progress has been and needs to be the filling of our needs in the many small articles made from sheet glass by reworking. As instances we may mention what is known as non-shatterable or duplex glass for gas masks and eye-protecting goggles, wind shield glass for submarine chasers, airplane cowls, port holes, instrument faces and so forth. The most usual means of production is by welding two sheets of desired thickness with an included sheet of water white pyralin under pressure and steam heat. Why may not this included sheet be any desired color or carry the numerals of any desired dial and in goggles the necessary corrective color for the eyes?

There has been and must be more intensive development of machine beveling for thousands of beveled meter and instrument faces, for the trying of watch glass bevels and similar work.

Drilling for the insertion of posts, pivots and so forth is an important art. Recently the writer had occasion to investigate the large percentage of breakage in drilling flashed glass and was amazed to find how little information was in possession of those engaged in the work.

Production of light-correcting and diffusing glass from sheet glass by means of acid working and staining, whereby absolute control of color is obtained, should be developed.

One development of which the writer is aware promises an entirely new method of production of electric heat, by the use of a glass coated with a metal deposit which will carry a certain type current and heat the glass to any desired point.

The production of glasses for the filtering of different light rays is of great interest, and much work remains to be done in glass to allow only colors true to the spectrum to penetrate, and for the exclusion of ultraviolet and red, and also for X-ray work.

This paper would seem to indicate that we have done no work but that al together commercial; but curiously enough, to ou

credit is the only altogether new note in art glass, that known as opalescent and used in ornamental window work to reproduce absolutely any desired picture. For many years there had been glasses rolled which were mixtures of color with opal, but the late John La Farge doing window work in the 80's wondered if it were not possible to mix colors in glass while molten even as he would mix color on his palette. It was attempted and led to the establishment of a new industry which produced so numerous color and tone mixtures that anything in nature or art might be reproduced.

One of the greatest problems is the production of the proper types of light-directing and diffusing glasses. Prismatic glasses with various angles designed to turn the light into a plane parallel with the floor of any building have been worked out and largely used in practice. However, they are worked up and glazed frequently without reference to these rules, and the great defect to-day, other than this, seems to be that they are usually melted from common green-colored glass when at very little extra expense for decolorizing a clearer glass might have been produced, adding greatly to their efficiency.

Regarding diffusive sheet glasses almost the first study, and certainly the most exhaustive, was given to this during the development of the lighting plan for the Panama Pacific Exposition. All available glasses were studied and while the ideal glass was not made for the desired purposes a fund of knowledge was accumulated.

Two types of diffusive glass would seem to be called for, one with great specular reflection and one with little reflection but the maximum diffusive and transmissive values. A glass of the former type is available but the latter is still wanting.

It was found that the same thing is true of these glasses as was said of prismatic glasses; that no great care had been taken as to the color and luster of the glass. It would seem for the slight expense involved that manufacturers would try to produce a better quality glass in these lines.

Diffusion by means of deflection within the mass, as in varying type of light opal glass carrying deflective particles in suspension, has reached a high stage of development and for light-enclosing purposes works very well.

THE MALINITE PROCESS FOR THE PRODUCTION OF SILLIMANITE REFRACTORIES

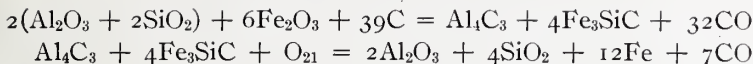
By A. MALINOVSKY

The Theory of the Process

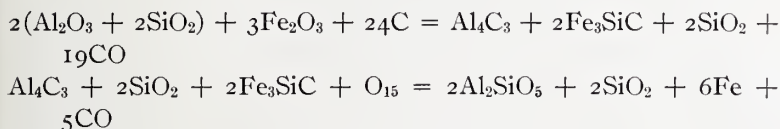
The Malinite process is a method of producing sillimanite refractories. The object of the process is to produce an extremely refractory material, having a neutral quality, for metallurgical structures, such as open-hearth and electric furnaces, converters, crucibles, and molds, where high temperatures and destructive slags are employed; also for the chemical industry and for chemical stonewares.

By this process any aluminous rocks or minerals can be converted into a stable compound of aluminum monosilicate, known in the ceramic art as sillimanite, and which resists high heat and slag. I have discovered that if aluminum silicate such as clays, halloysite, and other like aluminous rocks or minerals of wide occurrence are smelted in a cupola furnace (which I have specially designed for this purpose) together with a suitable reducing agent in proper amount, it is possible to regulate the volatilization of the silica by proportioning the amount of the reducing agent, so that it shall be sufficient to reduce all the silica, or to produce only a fractional reduction of the silica to any desired amounts, leaving only a part of the silica unreduced so as to convert all the charge into sillimanite, or only a part into sillimanite and the rest into fused quartz glass. It should be mentioned at this point that sillimanite or corundum does not combine with fused silica, nor with amorphous silica when it is available.

Preparing the materials for the fusing and charging the cupola are as follows: I take, for instance, the crushed raw material, and mix therewith a suitable reducing agent, as carbon, in the molecular proportion to the silica content in the rock or minerals as indicated in the following equations:



or



On the assumption that the above equations are all correct it is then evident that SiC is formed, and that the SiC gives up the carbon, though not as rapidly as if SiC were alone. It depends on the ratio of combined carbon and the effect of Si upon the quantity and condition of carbon. When SiC gives up carbon, leaving behind Si, this ignites spontaneously on coming in contact with the blast, forming first SiO and then SiO₂. The attraction between Si + O and then SiO + O is very strong, and much heat is produced by the combustion of silicon to silica.

The above equation of the combining reaction of Si and Fe is perhaps not the exact chemical combination that might take place, because we have for example ferrosilicon, which shows that Si is able to unite with Fe in all proportions. The iron may be absent and in that case more fuel must be added in the cupola. The proportions of the mixture may, however, be varied, as an excess of carbon over the calculated amount of silica is sometimes necessary in order to complete the reaction. The iron when added in the proportion from 3 to 6 per cent, as an ore or as an impure clay, can be mixed with the charge.

It should be made clear that the iron acts as a catalyzer, inasmuch as it accelerates the reaction and promotes more complete reduction of the silica. The iron alloys with the silicon, and it is thus that the silica is separated and volatilized, or sinks to the bottom of the furnace with the iron in the form of pure metallic iron or as ferrosilicon, or alloyed with copper.

When fusion commences in the first hot zone, or layer, reaction is taking place, and Fe, Si and C are set free. Consequently after this first reaction the rest of the reactions take place more rapidly. It is thus the iron which accumulates, as it is not eliminated from the charge by volatilization. It is very desirable that

titanium be present, as it detains the combination of iron with alumina, and, therefore, the iron can act continuously with the silica when the mass is brought to boiling.

It will be seen that the chemical process must go on continuously and consecutively as each thermic zone may permit it. This is evident because in two or three hours the temperature has reached the stage where the heaviest fumes of silica emerge and the heaviest deposit of SiO_2 takes place. This volatilized silica has an apparent specific gravity of 0.47 and is snow-white.

The volatilization of the silica depends upon the total amount of carbon and iron present, and also upon the temperature of formation and perhaps also upon the presence of other elements, to create conditions favorable to dissociating the SiO_2 into $\text{Si} + \text{O}_2$, and the formation of SiC , which later is broken up when in turn SiO_2 is again formed by reoxidation.

From my standpoint, as I conceive this chemical action, it must be evident that the formation of the carbides such as Fe_3C , SiC , Al_4C_3 and CaC_2 and others are gradual, and as quick as they are formed they are changed again to oxides. Only the Fe remains in a metallic state. However, some of it is expelled in the form of magnetite iron (Fe_3O_4) as fine particles carried out by the blast. The iron which is in a combined state with the material or fused mass is in a magnetic state and, therefore, renders the whole mass almost magnetic.

A very interesting test was made on this subject. We sent some of our material to be tested by magnetic separation to Dings Magnetic Separator Co., Milwaukee, Wis. They found the following results: Laboratory sample 270 (20 mesh).

| | Per cent |
|-------------------------------|----------|
| "A" medium magnetic..... | 0.73 |
| "B" first high magnetic..... | 88.50 |
| "C" second high magnetic..... | 6.37 |
| "D" non magnetic..... | 4.40 |

If all the results obtained by my experiments, observations, and my experience in my process are correct, then I freely can state that C or CO, solid or in gaseous state, does not entirely break up the SiO_2 into $\text{Si} + \text{O}_2$, but this is rapidly accomplished

in the presence of Fe, Mn, or Ti. The proper quantity of Si volatilization and carbide formation varies with the nature and amount of impurities contained in the rock or minerals, temperature, and hydropscopic state of the blast.

Operation of the Furnace

The charging of the furnace is accomplished as follows: Figure 1 represents the furnace and blower. The outside shell of the furnace is of common iron such as an old boiler shell; or an old

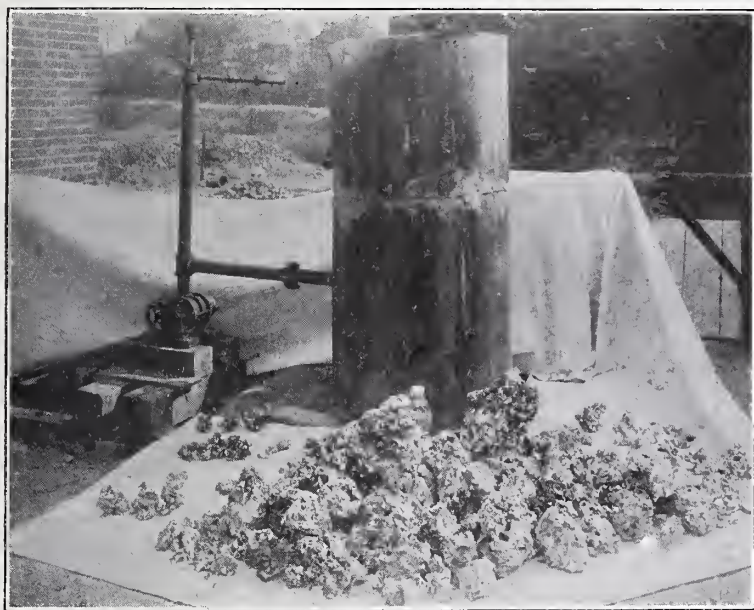


FIG 1.—Furnace with blower and fused product.

smokestack can be used. This is lined with good fire bricks. The bricks are then protected with a wall, about 4 inches thick, of the material which is to be fused, crushed fine. A mold is placed inside of the furnace, and the raw material is rammed all around between the inside of the furnace and the mold in a tapering shape, to about one inch thick on top. This will protect the fire bricks from becoming fused and at the same time will pre-

vent the fused charge from adhering to the fire bricks. Thus the fused mass can be discharged freely in a very short time. When the ramming is finished the mold is removed.

This protection of the raw material which is not mixed with coke is 4 inches thick only to the line where the mass shrinks to its limit. From this line it then tapers gradually to one inch at the top of the furnace. The reason for this arrangement is that when the furnace is fully charged and the heat commences to rise, the charge will shrink and sink down to this line, which is about four feet or so from the top of the furnace. The raw clay which is not mixed with coke or coal, and which I call a protective wall, will fall gradually on top of the charge and will hinder the free passage of the volatilized silica. To avoid this I usually mix the raw clay from that point on with a little coke. The top of the furnace from this line can be removed if so desired in order that the volatilized silica does not cling to the wall and become re-fused in the mass, which is a great detriment. The silica fumes should always pass off freely.

Large lumps of coke are placed on the grate bars for a height of about 30 cm. These big lumps of coke are used in order to protect the grate bars from fusing. Coke is one of the best solid fuels for my process as it does not crush or disintegrate and carries the weight of the charge better than coal. The coke serves also to preheat the air. On top of this coke about 60 cm. small coke is placed, then a little kindling wood, on top of this small coke again about 15 cm. high. Then the fire is lighted and the blower is also run very slowly until a heavy smoke commences to rise. Then the crushed clay mixed with the crushed coke is put into the furnace, and the speed of the blower is gradually increased to furnish about 18,000 cubic feet of compressed air per hour under three pounds pressure.

The steam commences to rise, mixed with heavy smoke, and in about two hours the charge commences to sink down and the gas to burst into flame above the cupola. The rest of the charge, about one-third, is then put into the cupola. The blast of compressed air is forced through the 165 cm. high fuel bed of coke, becomes very well preheated, and is then forced through the hot

mass, producing combustion. The silica commences to be deposited on the furnace wall. This period is very well characterized by the yellow flame coming from the furnace.

It is very important in my process to have the heat from the bottom of the furnace, and therefore, enough fuel should be placed



FIG. 2.—Rod, which was immersed in the fused boiling mass, covered with sillimanite crystals.

to last through the whole process. The furnace must be heated under such a reducing condition in the beginning as to convert gradually all the Fe, Si and Al into carbides. It should be understood that reduction takes place only at temperatures where solid carbon takes up oxygen from the material. The quantity of CO_2 present inside the furnace is sufficient to retard the process of reduction greatly, while the CO_2 is usually too small to be formed by the action of CO alone on the raw material. These facts point to the probability that there must be a considerable amount of reduction of the material taking place by the action

of solid carbon in the upper part or zone of the furnace and that the resulting CO performs an additional reduction in the still higher zone.

To promote or hasten the volatilization of silica from a material of high melting point such as halloysite, bauxite or any other aluminous rock or minerals, fluorspar or cryolite can be used. I have found that cryolite is more desirable than fluorspar. Cryolite found in nature or the artificial variety can be used,

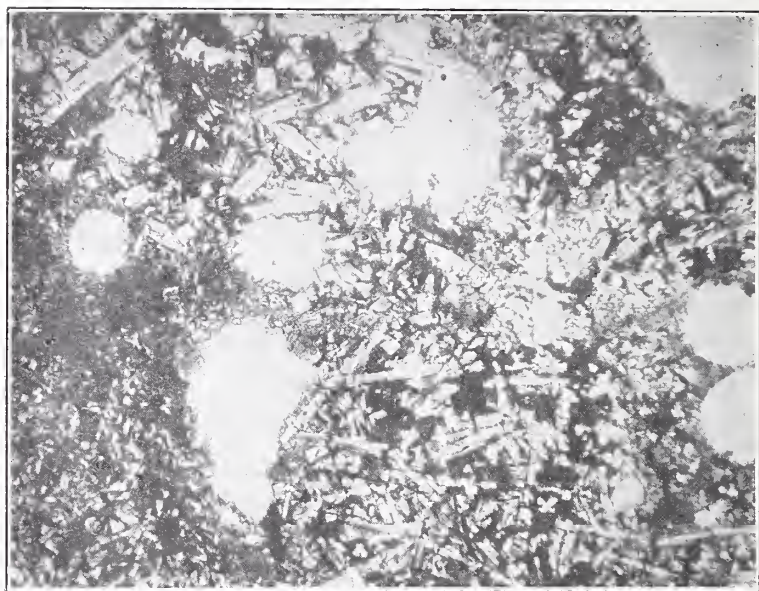
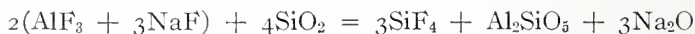


FIG. 3.—St. L. VI. B. taken in ordinary light. Note the development of sillimanite crystals and their variation in size from thin needles to comparatively large prisms. Note also the development and structure of the slag. Magnification—150 diameters.

or any other fluoride. If cryolite is used the volatilization of the silica is very rapid and the time is considerably shortened. Cryolite is a fluoride of aluminum and sodium $\text{AlF}_3 + 3\text{NaF}$. The action which takes place in the presence of cryolite with the silica is as follows:



The liberation of the fluorine gas at a very low temperature from the cryolite produces the combination with silica, forming silicon tetrafluoride, which escapes as such in the gas form. During this reaction the raw material commences to break up and will be porous. At the same time the heat is increasing in the furnace,

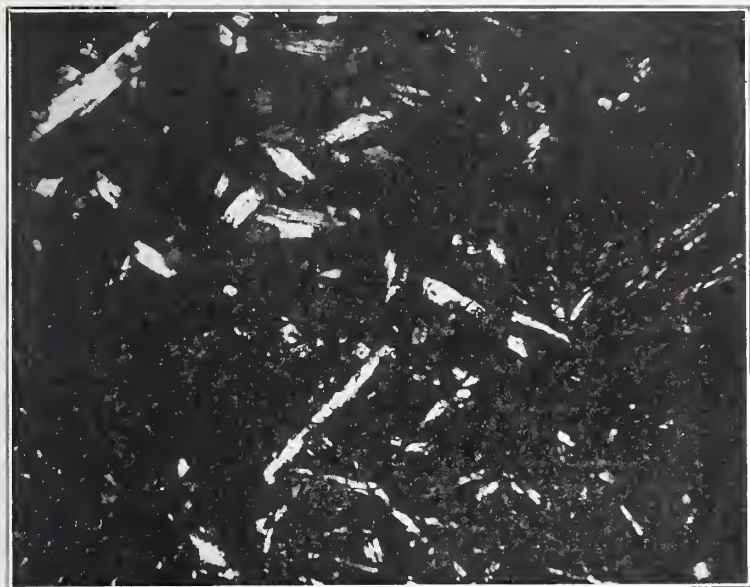


FIG. 4.—St. L. VI. B. taken in plane-polarized light with crossed nicols. Compare with figure 3. Note the apparent isotropy of the thin sillimanite needles as against the strong birefringence of the thicker prisms.

liberating the carbon which will act more energetically to reduce the silica to silicon. The above chemical equation shows that by using cryolite Al is introduced and the product is increased by one molecule of sillimanite and one molecule less of the silica has to be driven off. By using cryolite a purer product is insured and this is accomplished in a shorter time. The quantity of cryolite used depends on the raw material and the purpose to which the product is to be put.

After three hours the whole charge is brought to a dazzling, glowing, white heat, the yellow-violet flames indicating the com-

bustion of Si to SiO and then to SiO₂, and the mass is then at its thermic action. The mass, or properly the content of alumina and silica, is boiling which fact is noticed by the roaring noise inside the furnace, and the silica is volatilizing in a dense white bluish, and lastly, in brownish fumes, for about two hours. At the end of five hours the whole process is completed, and air is



FIG. 5.—Ind. V. B. taken in ordinary light. Compare with figure 6. Note the size and development of sillimanite crystals imbedded in the interstitial glass and slag. Magnification—150 diameters.

blown into the cupola through the fused mass in order to produce cells resembling those of diatomaceous earth. The specific gravity of this fused mass varies from 2.62 to 2.86.

The furnace is provided with an exit pipe through which the fumes and gases are withdrawn and pass through into a settling system, tank, box, room or bags.

The hood can be removed freely to both sides and also lowered or raised. The hood is suspended above the furnace, and a

vacuum is created so as to collect all the fumes, and by this means the cupola is converted into a half vacuum furnace, or I may say blast on bottom and vacuum on top. The volatilized silica can be utilized for many useful applications in the arts. Its value is greater than that of the vitreous form.

By this process and system it should be clear that it is possible to effect a complete separation between the fused mass and alka-



FIG. 6.—Ind. V. B. taken in plane-polarized light with crossed nicols. Note the isotropy of the glass and slag.

lies, and also silica if desired, in a more economical manner than by the use of an electric furnace.

The fused mass can be removed in different ways, the cupola being so designed as to accommodate varying conditions. The mass can be removed at the bottom with the cupola in place, or the cupola can be removed and leave the fused mass standing in place on the grate bars, or the mass and cupola can be removed, and another cupola, already charged, set up on the place, and

the operations can begin at once. With this system a continuous process is established. You will kindly note that the cupola can be taken apart without interfering with the process. Therefore, if batteries of cupolas are built, the fusion process is not hindered at any stage, and the whole process is more economical, as time is saved and the production is largely increased.

Properties of the Product

After the mass is removed it is broken up and ground to the required fineness, the iron having been separated out by a magnetic device. It is very interesting to note that almost all the iron and copper collects on the bottom of the fused mass in big nodules. From the top to the center, the mass is almost entirely free from iron and copper. The iron on analysis showed that it is alloyed with silicon, copper and zinc; a small amount of gold was also found.

The fused mass obtained by the process is a product of a very high refractory quality, free from expansion and contraction at any degree of temperature, and it will not warp, crack, nor spall from changing temperature.

Sillimanite so produced by the separation from such a highly viscous magma solution at such high temperature without the addition of any flux is a stable compound of alumina and silica. Research in thermal investigations by many investigators has shown the existence of only one aluminum silicate formed from fused mixtures in crystal form. This is sillimanite, Al_2SiO_5 , with a melting point of 1815°C .

It is not necessary to state that fusion tests made on the product of this cupola at different places showed many times that Orton cone 39, and in one case even cone 40, was fused and the cone made of the Malinite product remained unaffected. Melting points of cones 36, 37 and 38 are common from the fused mass.

Three sample bricks were placed in a high-temperature electric furnace, in contact with the carbon resistor plates. The electric current passed from plate to plate and there was often an arcing action of certain points, which would cause a local temperature of 6300°F . The furnace temperature was approximately 3000°F ., and under these conditions the Malinite brick was unaffected.

Our experience with magnesite bricks in this furnace has been that they scale off and disintegrate under the furnace conditions explained above.

Investigations made by different petrologists have demonstrated from different fused masses of different fusions that the crystals present have indentially the same optical properties as the crystals of sillimanite found in porcelain bodies. The

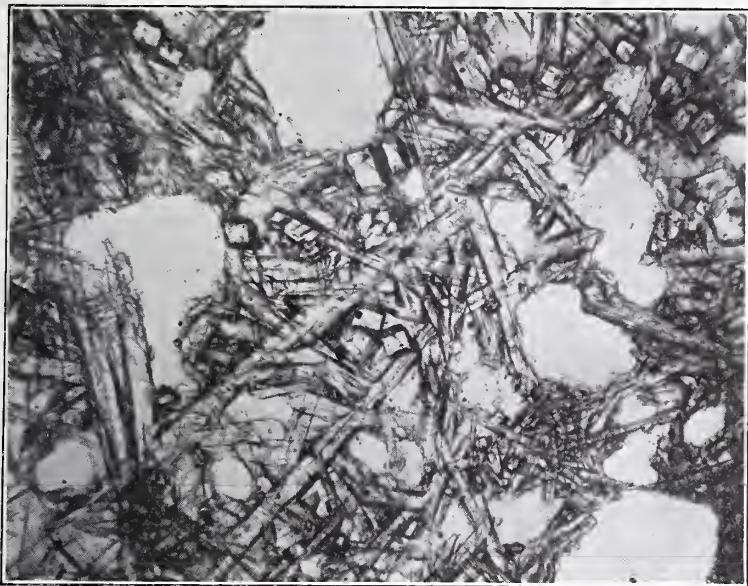


FIG. 7.—St. L. C. II. No. 13 (1) taken in ordinary light. Note the sillimanite coarse crystal development, the interstitial glass and the almost complete absence of slag. Magnification—150 diameters.

cuts demonstrate the fibrous form of the coarse crystals, aggregates of long unusually strong acicular crystals with parallel extinction and positive elongation. The interference colors are bright.

I have found in this work that the rate at which this crystallization proceeds depends a good deal on the temperature and fluidity of the magma solution from which these crystals develop. It seems to me that the created temperature of the thermal action

of alumina and silica increases the fluidity of the mass to such an extent that a molecular concentration of alumina and silica takes place, and on cooling from this high temperature the sillimanite separates from the mass. When enough silica is driven off by volatilization and only one molecule of silica is left behind in the mass in proportion to one molecule of alumina, sillimanite will separate out and the mass is converted wholly into sillimanite. If more of the silica remains in the mass, then sillimanite and glass are formed. This glass, however, may be the same composition as sillimanite, but even if it should be fused quartz, it is not a detriment to my product, because sillimanite remains uncombined and will always separate out as such.

Should the magma be siliceous and contain calcium, sillimanite formation is retarded or diminished. In this line I did some very interesting work. I took precipitated alumina, silica and calcium and mixed them in the following proportion:

| | A | B | C | D | E | F |
|--------------------------------------|------|------|------|------|------|------|
| SiO ₂ | 36.1 | 35.3 | 34.5 | 33.6 | 11.1 | 32.2 |
| Al ₂ O ₃ | 61.5 | 60.0 | 58.6 | 57.3 | 56.0 | 54.8 |
| CaO..... | 2.4 | 4.7 | 6.9 | 9.1 | 32.9 | 13.0 |

These mixtures were made into small briquets and burned to cone 14, some were burned twice. After they were cool, small pieces were broken off and examinations made under the microscope. These crystals showed different optical properties than was the case in the former fusions; the refractions were not so strong.

When treated with hydrofluoric acid the samples marked D, E, F were dissolved and a residue of powder left, which on analysis were found to be alumina, calcium and a trace of silica. The silica was almost all volatilized. This demonstrated that the crystals noticed under the microscope were not sillimanite (Al₂SiO₅) but that they were wollastonite (CaSiO₃).

The pieces which did not contain lime were not attacked at all by the hydrofluoric acid treatment. The pieces marked from A to C were a little attacked by the acid.

I also made a very careful study and investigation of the formation of sillimanite with pure kaolin, fire clays and halloysite, but have failed to find sillimanite so far in the above samples

burned in a commercial kiln. Numerous statements are given and published, in text-books and other literature, that clay decomposes into Al_2O_3 and SiO_2 . LeChatelier, Mellor and Holdcroft, Sosman, Klein and other investigators state that china clay decomposes and gives a product of free silica, alumina and water. The former two, however, are said to recombine in part again to



FIG. 8.—St. L. C. II. No. 12 (1) taken in plane-polarized light with crossed nicols. Compare with figure 7. This photograph accentuates the difference between the sillimanite crystals and the isotropic glass.

form sillimanite when heated above 1200°C . I have tried with two different washed kaolins, four different fire clays, and three different halloysites to produce sillimanite. The kaolins were purchased from Roessler, Hasslacher Chemical Company, the halloysites came from Indiana, Georgia and Alabama, and the fire clays from Olive Hill, Mount Savage, Ohio and St. Louis, Mo.

These materials were ground and made up in small briquets of $\frac{1}{4}$ inch size, dried and heated to Orton cone 14 for the length

of 96 hours. After they were allowed to cool, chips were broken off for microscopic examination. No sillimanite was noticed, except in very small pockets in the St. Louis fire clay. A few very fine crystals were visible with a powerful lens, but they were very uncertain to be sillimanite.

The samples were then placed in the kiln again, on the back wall, and heated four more times to cone 16, and one time to 18. After they were allowed to cool to atmospheric temperature, small chips were broken off again and microscopic examinations made. No signs of sillimanite crystals were found in the kaolin, nor in the halloysites, nor in the Olive Hill and Mount Savage clay, but the St. Louis fire clay and also the Ohio fire clay contained a considerable amount of fine crystals in nests scattered throughout the body.

This demonstrates that fire bricks made of pure fire clay, free from alkalies, have to be heated above 1400°C . in a prolonged heat and then allowed to cool slowly to form a few crystals of sillimanite. The formation of the sillimanite crystals in fire bricks is produced only by prolonged heating at high temperature, and is remarkably better developed in the presence of feldspar minerals and micas in the clay.

Mr. A. A. Klein made a very careful investigation in this line on washed North Carolina kaolin and on English kaolin and found small crystals of sillimanite in the two clays heated in a platinum resistance furnace for five hours between 1400 and 1450°C .¹

After I had mixed the raw kaolin, halloysite, and fire clays with 25 per cent feldspar and subjected the mixtures to high temperature, cone 14 for 96 hours, they were allowed to cool and chips were broken off. It was found by microscopic examination that in every sample crystals were noticeable in abundance.

The circumstantial evidence of this work demonstrates that the work done by Vernadsky, Zoellner, Klein and others prove my statements, that in a porcelain body the chief cause of the presence and the separations of the sillimanite crystals from the magma solution, when allowed to cool down slowly from the high temperature of 1400°C . to ordinary atmospheric temperature,

¹ Bureau of Standards *Tech. Paper* 80.

is the solution of the kaolinite by feldspar and more so by orthoclase than by albite. Therefore, in this case kaolin and feldspar are the only essential materials to create conditions for the production of sillimanite crystals.

Vernadsky found that sillimanite crystals are produced whenever mixtures rich in kaolin and feldspar are subjected to a tem-

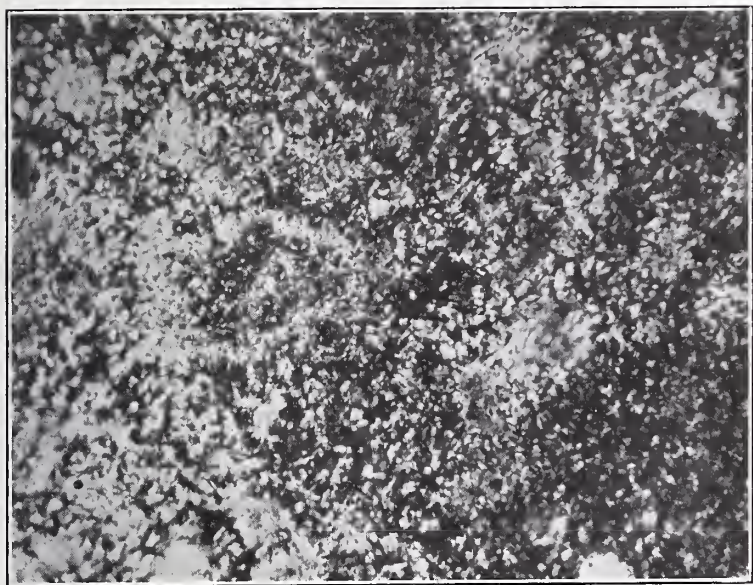


FIG. 9.—St. L. C. II. No. 13 (2) taken in ordinary light. Compare with figure 10. Note the small mainly anhedral sillimanite crystals, the opaque slag and the glass sometimes rendered "muddy" by amorphous sillimanite inclusions. Magnification—150 diameters.

perature over 1300° C. The velocity of crystallization of sillimanite in alkaline bodies is governed by time, temperature, and the rate of cooling. In porcelain bodies the slower the cooling the more complete is the process of crystallization, as by this slow-cooling process the corresponding chemical composition arranges itself into crystals; a part of the liquid will recrystallize before the remaining magma commences to solidify. In quick cooling of a

porcelain body or of fire brick the magma solidifies so fast that the chemical components have not the time to form crystals.

In the late work of Albert B. Peck, published in the *JOURNAL OF THE AMERICAN CERAMIC SOCIETY*, 2, 175 (1919), he also states, as do Plenske and Zoellner, that the size of the crystals developed appears to be influenced by the three factors; the amount of feldspar or other fluxes present; the mobility of the feldspar, as affected by the temperature of firing; and the length of time of firing. By my process the crystals are developed in a few hours and cooled in about one hour, and unusually large and coarse crystals of sillimanite not known to the present are produced.

Samples subjected to the hydrofluoric acid test have given the following results:

| Sample | Length of treatment | Per cent loss |
|---------|---------------------|---------------|
| 19..... | 1 day | 180 |
| 20..... | 3 days | 170 |
| 21..... | 6 days | 18.5 |
| 22..... | 6 days | 4.0 |
| 23..... | 12 days | 5.96 |

Samples 22 and 23 were chips from the fused product as it came out from the furnace. The average analysis of these two samples was as follows:

$$\text{SiO}_2 = 37.1 \text{ per cent, Al}_2\text{O}_3 = 62.9 \text{ per cent}$$

These crystals once formed are stable and cannot be destroyed in commercial furnaces. But we know that in fire bricks, the bricks become gradually weaker mechanically, as the crystals are formed and the alkalis volatilize. I have noticed in fire bricks made from fire clay, that when they are exposed to repeated heating to high temperatures, and allowed to cool slowly, the small amount of lime which the clay contains does not hinder the formation of sillimanite. But as soon as sillimanite commences to be formed, alkalis and some of the silica commence also to volatilize. The volatilization of silica is especially noticeable in the presence of solid carbon when the furnace is under reducing condition. This applies to all refractories containing silica, even bauxite or flint.

Therefore, it can be said that all the refractories made from fire clay, flint clay, or bauxite are not stable compounds for linings in furnaces, as they are exposed to continuous expansion and contraction and chemical action. Therefore, their life is limited at prolonged high temperatures at which they suffer mechanical

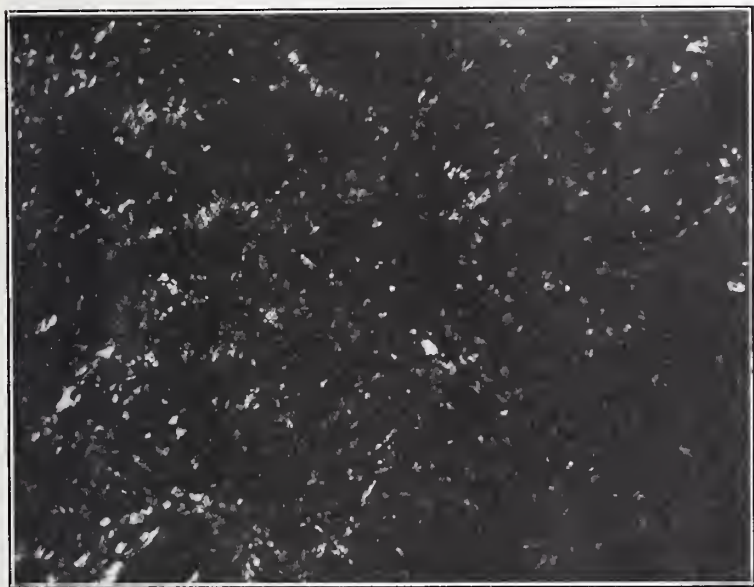


FIG. 10.—St. L. C. II. No. 13 (2) taken in plane-polarized light with crossed nicols.

destruction. Under the prolonged high temperature, the feldspar mica and lime present in the clay commence to fuse at 1200° C., as demonstrated by Le Chatelier and Bogitch, forming solutions which cause softening and so dissolve the more refractory substances, leaving cavities for accumulation of ashes, carbon and other substances. This causes further destruction of the brick until they gradually melt away. The vapor of different substances and the volatilized alkalies from the fuel and materials also, cause fluxing actions on the surface of the brick, forming solutions from which the sillimanite is more apt to separate.

The fused part goes continually deeper and deeper into the brick.

All this crystallization process occurring in the bricks during their use is very irregular and is always accompanied by contraction in volume. At the same time local strains are set up through the whole brick, causing rupture of the brick, or may be the whole wall has to give away. The experimental evidence of the many

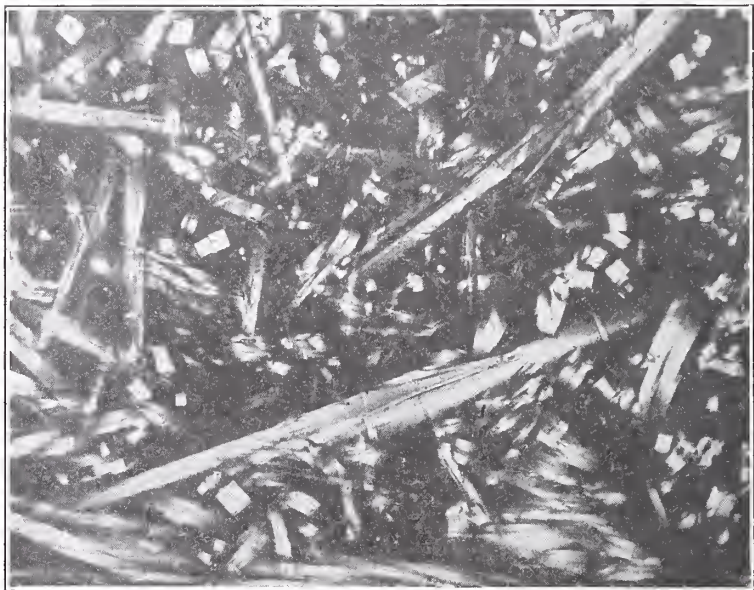


FIG. 11.—St. L. C. III. No. 14 taken in ordinary light. Compare with figure 12. Note the presence of predominating sillimanite and the size as well as the development of the crystals of this constituent. Note also the practical opacity of the glass rendered so by the comparative thickness of the section. Magnification—115 diameters.

tests made at different places on Malinite is proof of the stability of the sillimanite crystals produced by my process.

It is of capital importance in the manufacture of refractories to have always a pure uniform material. We know this is very difficult to do with the present methods of working clay; perhaps one strata of the fire clay is very pure while the adjoining

strata is contaminated with materials which make the clay worthless for refractory purpose. It can be seen that with my process it is very simple to overcome this trouble, and a uniform material is always obtained. Plans can be better and more systematically arranged with a perfect control of the raw material at every point and stage in the manufacturing operations. The variation in raw material from time to time is avoided and the process at every stage is brought under full control.



FIG. 12.—St. L. C. III. No. 14 taken in plane-polarized light with crossed nicols.

Here I want to illustrate the analysis of raw and cupola product after the raw materials are fused. The first analysis is from halloysite. You will kindly notice the higher per cent of lime and magnesia, also the presence of some titanium. I am very certain that no titanium is present in this halloysite in the raw state, as I made numerous analyses, I may say thirty or more, and never found titanium. I found cobalt, zirconium and manganese in

traces, but never titanium. The titanium in this analysis is brought in by the impurities of the coke. We used a coke which showed on analysis 15.50 per cent of ash, called Turkey Knob coke.

| | Raw halloysite | Calculated, The moisture is omitted | The fused product |
|--------------------------------------|-------------------|--|----------------------|
| SiO ₃ | 34.06 | 47.54 | 17.16 |
| Al ₂ O ₃ | 33.07 | 46.16 | 78.39 |
| Fe ₂ O ₃ | 3.11 | 4.35 | .89 |
| CaO..... | .49 | .68 | 1.50 |
| MgO..... | .42 | .59 | .29 |
| Alk..... | .49 | .68 | 0.36 |
| TiO ₂..... | ..... | ..... | ..... |
| Moisture..... | 28.53 | ..... | ..... |
| | <hr/> | | |
| | 100.17 | | |

St. Louis fire clays which we have received:

| | 1 | 2 | 3 |
|--------------------------------------|-------|-------|-------|
| SiO ₂ | 47.25 | 52.20 | 53.50 |
| Al ₂ O ₃ | 28.22 | 26.92 | 28.75 |
| Fe ₂ O ₃ | 4.13 | 2.68 | 3.84 |
| CaO..... | .70 | 1.00 | 1.60 |
| MgO..... | 1.77 | 1.88 | 0.87 |
| Alk..... | .76 | 0.51 | ... |
| TiO ₂ | 4.55 | 4.10 | 4.10 |
| H ₂ O | 3.80 | 10.70 | 7.30 |
| Volatile matter | 8.82 | | |

In the third analysis the alkaline content is missing, as it was not sought for.

The analysis of the fused product from St. Louis fire clays are as follows:

| | | | | | |
|--------------------------------------|-------|-------|-------|-------|-------|
| SiO ₂ | 32.60 | 33.10 | 38.10 | 36.30 | 37.50 |
| Al ₂ O ₃ | 63.84 | 63.59 | 56.17 | 58.95 | 57.94 |
| Fe ₂ O ₃ | 1.62 | 1.57 | 2.61 | 2.40 | 2.16 |
| CaO..... | .89 | .63 | 1.10 | .65 | .80 |
| MgO..... | .32 | .21 | .49 | .22 | .22 |
| TiO ₂ | .67 | .82 | 1.12 | .95 | 1.10 |

The specific gravity of the fused mass varies from 2.04 to 2.20 and in some cases to 2.66. The brick, $9 \times 4\frac{1}{2} \times 2\frac{1}{2}$ inches, weighs 4.280 grams or 9.416 pounds and have an apparent

gravity of from 2.40 to 2.69. The analysis of the volatilized silica is as follows: SiO_2 94.5, Al_2O_3 0.50, CaO 0.60, MgO 0.51, alkalis 3.67, and the specific gravity varies from 0.471 to 1.875.

The fused products when removed from the furnace were carefully weighed after every fusion. The charge of raw material placed in the furnace weighed 600 kilograms. The average product taken from the furnace after the fusion was completed weighed 328 kilograms. This contained an average of 40.85 kilograms of iron, which had an average analysis as follows: Si 3.80, Al 1.20, Fe 44.86, Ti 49.14, Cu 0.09, and C 0.89. Many big pieces resembling copper coated with titanium, with a red copper metallic luster, were found. In metallurgy practice it is well known that titanium cyanonitride, Ti_5CN_4 is formed in the slag of blast furnaces in which titaniferous iron ore is worked, and that it is found in the form of cubes with copper-red metallic luster.

Microscopic Examination of Samples

The following is a report made by Mr. A. A. Klein on the microscopic examination of some of the products made by this process.

St. L. VI. B (see figures 3 and 4).—This sample was a gray sintered one showing a great number of fine spheroidal pores. The constituents found were sillimanite, glass, slag, and an extremely small amount of amorphous sillimanite.

A study of the microstructure by means of a thin section showed that there were two distinct types depending apparently upon the states of sub-division of the raw materials entering into the product. Such a condition is also found in other types of refractories. That portion of the product formed from coarser raw material contained, in general, fine sillimanite in intergrown fibrous crystals which sometimes were too thin to show double refraction. Amorphous sillimanite was also found here.

The main portion of the sample, however, consisted mainly of crystallized sillimanite occurring in the characteristic long, prismatic crystals which varied in length from under 0.01 mm. to 0.5 mm. These were embedded in a low refracting, colorless to yellow glass and in a black opaque slag.

The sillimanite needles which occurred distinctly intergrown and intertwined were longer and thicker than those normally found in porcelain bodies, but their optical constants were identical with those given for artificial sillimanite, namely, $\alpha = 1.638$, $\beta = 1.642$, and $\gamma = 1.653$. The character of the principal zone was positive. The extinction was parallel and the inter-

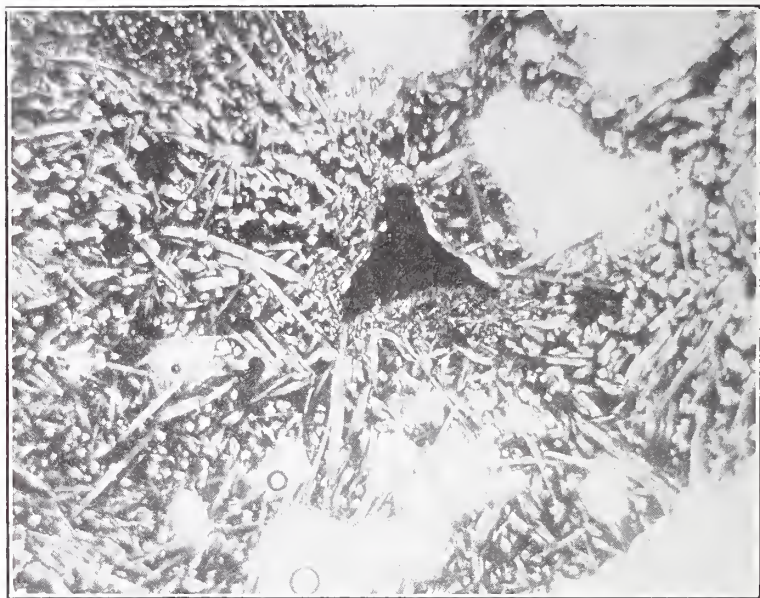


FIG. 13.—St. L. C. III. No. 14 taken in ordinary light. Note the opaque material at the center most of which possesses a metallic luster. This photograph gives a bird's-eye view of the production at low magnification—25 diameters.

ference figures were biaxial with a positive optical character and a small optic axial angle. There was nothing found optically that would indicate another modification of sillimanite, nor even the presence of any great amount of extraneous oxides held in solution.

A quantitative determination of the index of refraction for the glass gave a value for sodium light equal to 1.510 ± 0.003 . The

opaque slag occurred generally in irregular forms which showed no metallic luster but rather appeared dull in reflected light.

Ind. V. B (see figures 5 and 6).—Visually, as well as microscopically, this sample rather resembled the product previously described. The constituents were sillimanite, glass, slag, and amorphous sillimanite.

As in the case of the previous sample, the microstructure was of two types: first, a uniformly fine crystalline one which was formed from original coarse particles of raw material, and, secondly, the predominant, distinctly coarser crystalline type which was formed from the reaction of materials in a comparatively fine state of sub-division.

The former type generally consisted of very small sillimanite needles which rarely exceeded 0.05 mm. in length and were generally associated with relatively small amounts of amorphous sillimanite. In a few instances, however, the amorphous sillimanite was the chief constituent.

As stated above, the coarser crystalline type was predominant and here the chief constituent was crystallized sillimanite which occurred in a ground mass of colorless glass and opaque slag.

The sillimanite occurred mainly in well-developed crystals of length varying from about 0.01 mm. to 0.08 mm. Optically the crystals were identical with artificial sillimanite. The glass was of a slightly lower index than in the previous sample, the value for sodium light being 1.503 ± 0.003 .

St. L. C. II (see figures 7, 8, 9 and 10).—There were two distinct products found in this sample: (1) A white to grayish white vitreous body; (2) a grayish brown sintered product which occurred to a greater extent than (1).

(1) The constituents here were sillimanite with smaller amount of colorless glass and a very small amount of opaque slag.

The sillimanite crystals were well developed and occurred as much intergrown prisms which attained a maximum length of about 1 mm. Optically, this material agreed with the constants found for artificial sillimanite. In the interstices between the sillimanite crystals and acting as a ground mass for them, oc-

curred the colorless glass which was present to an extent of at least 30 per cent. The refractive index of the glass for sodium light was 1.514 ± 0.003 .

(2) The constituents here were sillimanite, amorphous sillimanite, alpha alumina, slag and glass. The sillimanite crystals were generally anhedral, irregular and showed prismatic development to only a slight extent. The largest crystal measured

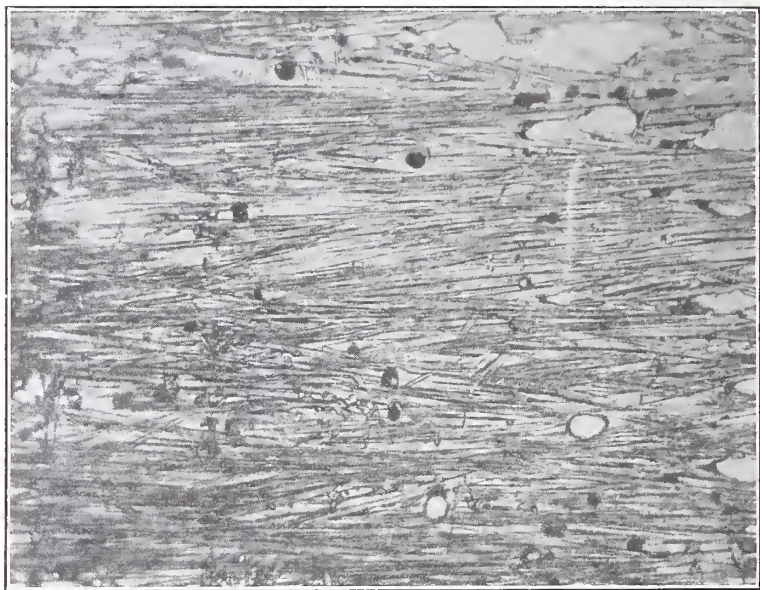


FIG. 14.—I. Ind. taken in ordinary light. Note the extremely coarse crystals of sillimanite and the globules of opaque material. Magnification—25 diameters.

under 0.2 mm. in length and most of them were under 0.02 mm. Despite their minuteness and due to their relative thickness, practically all showed double refraction. The refractive indices, which were the only constants that could be obtained with high accuracy, agreed with those given for artificial sillimanite.

About 15 per cent of alumina was found in small anhedral crystallites intimately associated with the fine crystalline aggregates of sillimanite. Some of these attained 0.1 mm. and in

all the determinable optical constants agreed with those found for alpha alumina. As in the products previously described, the colorless glass and the slag associated with it occurred as a matrix cementing the crystals of sillimanite and corundum.

St. L. C. III (see figures 11, 12, and 13).—This sample was a grayish black slag-like product with a stony appearance. It was quite porous, the voids being irregular to spheroidal and



FIG. 15.—I. Ind. taken in plane-polarized light with crossed nicols. Compare with figure 14. Note the two sets of parallel grouped sillimanite crystals one of which is practically in complete extinction.

filled in some instances with thin white to brassy yellow globules possessing a metallic luster. Their chemical composition is unknown but they appear to be at least in part ferrosilicon.

The constituents of the grayish black stony product were sillimanite, glass and the opaque material with metallic luster.

The sillimanite occurred as anhedral long, colorless, prismatic crystals which optically agreed with the data found for artificial

sillimanite. The crystals varied in size and reached a maximum length of 1.7 mm.

The glassy matrix was colorless to greenish and of a refractive index for sodium light equal to 1.510 ± 0.003 . The slag occurred intimately associated with the glass in the form of minute dusty particles.

The opaque metallic constituent was found in rounded to irregular masses. With reflected light a portion of these at least were found to have metallic luster although in some cases the major portion of the grain was dull. It is impossible to state from this examination just what the actual chemical composition is, except that the material is in part metallic and may, therefore, contain such elements as iron, copper, silicon and so forth.

I. Ind. (see figures 14 and 15).—This was a grayish white, fused, vitreous, fibrous product. The constituents were sillimanite, glass and opaque material. The sillimanite was in the form of long, fibrous crystals whose length was limited only by the size of the sections, namely, 8 mm. These fibers showed a tendency toward parallel grouping and in a few instances an angle of approximately 15° was included between two sets of grouped fibers.

The glass occurred as the matrix between the sillimanite crystals as well as in thin stringer-like inclusions parallel to the long direction of the sillimanite fibers. The refractive index was approximately the same as in some of the products previously described: namely, 1.515 ± 0.003 .

The opaque material was in the form of extremely small globules, most of which gave decided reflections when viewed in reflected light and are probably of a metallic nature.

The alumina crystals were present to an amount not exceeding a few per cents and are very small. Owing to their minuteness and the fact that they were intimately associated with the sillimanite crystals, their identity was established only through a study of immersed grains since their presence was not apparent in the thin section.

Conclusion.—Owing to the lack of information given it is impossible to discuss and compare the products examined, other than to state that with one exception the chief constituent in

every case was crystallized sillimanite, that this constituent agreed optically with the constants found for it in previous investigations and that the development as well as the size of crystals was much coarser than that normally found in porcelain and in ordinary refractory clay bodies.

Conclusions

1. It would be impractically, if not impossible, to convert fire clay into sillimanite by the methods employed in the manufacture of silica and magnesite brick.

2. The microscopic and petrographic examination of the sillimanite developed by my process leads to conclusion that the sillimanite developed by my process, free from any flux, is a stable compound and in comparatively larger crystals than any sillimanite crystals yet produced.

3. No mineral particles remain unaltered. This produces a compound of great resistance against chemical action and thermic changes, whereas in a compound containing unaltered mineral particles continuous alterations will take place, causing spalling and deterioration of the refractories.

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The author also wishes to express his thanks to Professor Rollin D. Salisbury and Mr. Harold W. Tomlinson, and Mr. A. A. Klein for the preparation of microsections, and for the special attention given the examination, microphotographs and reports,

especially to Mr. Klein, who by tedious work helped to solve the question of the presence of corundum with the fused sillimanite.

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I am also greatly indebted to Mr. J. H. Campbell, chief chemist and chemical engineer for Robert W. Hunt & Company, Chicago, for his aid, suggestions and interest for years in this work, for his good advice, and for checking some of my analyses. Also to Professor J. W. Richards for his valuable advice and corrections.

SILICIOUS SAGGER MIXTURES¹

By M. R. HORNUNG

Introductory

The object of this work was the study of mixtures of clay and free silica in the form of chert and gannister (quartzite) for the purpose of increasing the resistance to load conditions at kiln temperatures. The particular problem was the construction of a mixture for saggars carrying heavy loads and fired to a temperature corresponding to cone 16.

The gannister was obtained from the Hays Station plant of the Harbison-Walker Refractories Co. and represented the regular type used in the manufacture of silica brick. It came from the Mt. Union, Pennsylvania, district. Its mineralogical character has been described in detail by Ross and Insley and Klein.²

The chert was secured through the kindness of Mr. Wilber Stout, Ohio Geological Survey, and Mt. T. G. McDougal, Flint, Mich., and was that found at Flint Ridge, near Zanesville, Ohio. It possessed the characteristic crypto-crystalline structure with varying amounts of quartz. The chert of coarser structure was higher in recognizable quartz grains, while that showing a finer texture consisted largely of crypto-crystalline material.

In order to make the results of as general application as possible three types of bond clay were used, namely, the Tennessee and Kentucky ball clays and the bond clay from near Enid, Mississippi. In addition Georgia and Florida kaolin were introduced in some of the mixtures and later calcined Pennsylvania flint clay.

Preparation of Mixtures

The preparation of the bodies was begun by intimately mixing the constituents in the dry state, the clays having been ground to pass a 20-mesh sieve. The pugging of the batches, which weighed fifty pounds each, was done in a kneading machine made

¹ By permission of the Director, Bureau of Standards.

² Bureau of Standards, *Tech. Paper* 116 and 124.

by the J. H. Day Co. The batches were then thoroughly wedged and from each mixture two pots were jigged, which were 10 inches in diameter and 8 inches high with walls 1 inch thick. The dried saggers were fired to cone 13 in 48 hours and held at the maximum temperature for one hour.

Tests

It was at first planned to make the load test the principal feature of examination, but it developed that the critical point involved was not resistance to pressure but one of resistance to heating and cooling. Hence a load test was made only after a body had behaved satisfactorily with reference to heating and cooling.

The load test was conducted in the usual manner as for fire brick, but the pressure adopted was 40 pounds per square inch and the maximum temperature 1375°C. , held for one hour.

The heating and cooling test consisted in stacking the saggers or pots in a bung, applying a load of 200 pounds upon the top specimen and heating the bungs. The temperature was raised at the rate of 100°C. per hour to 1200°C. , and the cooling took place at the rate of 200°C. per hour for the first four hours and from there on at a much slower rate, as in the natural cooling of a kiln. A fusion test was made on a few mixtures only.

The field covered in this work consisted of three series of bodies. Each series was divided into two parts, A and B, indicating the addition of chert and gannister, respectively.

Series I-A

The compositions of the members of this series are given in table 1.

TABLE 1

| No. | Chert. | Tenn. | Ky. | Miss. | Ga. | Fla. | Chert | Chert | Chert |
|-------|----------|----------|----------|----------|----------|----------|-------------|-------------|------------------|
| | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | 20-40 mesh. | 40-80 mesh. | through 80 mesh. |
| | | | | | | | Per cent | Per cent | Per cent |
| 1.... | 80 | 6.66 | 6.66 | 6.66 | ... | ... | 32 | 12.00 | 36.00 |
| 2.... | 75 | 8.33 | 8.33 | 8.33 | ... | ... | 30 | 11.25 | 33.75 |
| 3.... | 70 | 10.00 | 10.00 | 10.00 | ... | ... | 38 | 10.50 | 31.50 |
| 4.... | 65 | 11.66 | 11.66 | 11.66 | ... | ... | 26 | 9.75 | 29.25 |
| 5.... | 60 | 13.33 | 13.33 | 13.33 | ... | ... | 24 | 9.00 | 27.00 |
| 6.... | 55 | 7.50 | 7.50 | 7.50 | 11.25 | 11.25 | 22 | 8.25 | 24.75 |
| 7.... | 50 | 8.33 | 8.33 | 8.33 | 12.50 | 12.50 | 20 | 7.50 | 22.50 |

As shown in table 1 the chert was ground and screened to three sizes, *viz.*, 20-40 mesh, 40-80, and dust passing the 80-mesh sieve. It was desired to produce the densest body possible, since for the particular work in view the saggars were to be subjected to heavy loads. According to Kirkpatrick¹ the combination

| | |
|---------------------------|-------------|
| 20-40-mesh size..... | 40 per cent |
| 40-80-mesh size..... | 15 per cent |
| Through 80-mesh size..... | 45 per cent |

should yield this condition.

The pots made from the compositions of series 1-A had a very good appearance when they came from the kiln. They possessed a good ring and were entirely free from surface cracks. Their fire expansion or contraction, measured from a line six inches long drawn on the dry pots, was found to be as follows:

| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|-------|-------|-------|-------|-------|-------|-------|
| Expansion or contraction, per cent..... | +3.12 | +1.95 | +1.82 | +1.04 | +0.65 | -0.52 | -1.56 |

It will be observed that a neutral condition, that is, neither expansion nor contraction, was found to prevail with between 60 and 50 per cent of chert. Of these mixtures 3 and 5 were subjected to the load test in which a pressure of 40 pounds per square inch, resulting in a total load of 1108 pounds, was applied upon the pots. Specimen 3 was badly fractured, evidently not due to the load effect but to the rapid cooling while under constraint. Specimen 5 was found to be cracked but not nearly as badly as 3 and showed a linear contraction of 0.21 per cent.

At this point the load tests were temporarily abandoned and the heating test, described above, applied. All of the pots were found to be cracked and those with the largest chert content showed the greatest amount of damage.

Series I-B

The mixtures of series 1-B were exact duplicates of series 1-A, except that ground gannister, was substituted for the chert. The same sizing of the silica material was maintained. Upon firing the specimens the mixtures 1 to 5, inclusive, were found to

¹ Bureau of Standards, *Tech. Paper*, 104.

be cracked, which made the heating and cooling test unnecessary. The pots of mixtures 6 and 7 were observed to crack when fired the second time along with some pots of the second series. The expansion or contraction of series I-B was found to be as follows:

| No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|-------|-------|-------|---|-------|-------|-------|
| Expansion or contraction, per cent. | +0.92 | +0.52 | +0.13 | 0 | -0.65 | -1.82 | -2.86 |

It will be noted that the expansion was appreciably smaller with gannister, and that neutral conditions prevailed in the mixture containing 65 per cent of quartzite. This shows clearly, as was to be expected from previous information, that the rate of inversion of the quartzite is slower than that for the chert.

The results thus obtained made it plain that the resistance to heating and cooling conditions was an inverse function of the total content of free silica. It was likewise evident that chert caused the bodies to be more resistant to rapid temperature changes than the gannister, though probably the mechanical strength induced by the latter is greater.

Series II-A

It was apparent from the preceding work that the amount of siliceous material had to be decreased; and it was decided to replace it in two ways; first, by means of calcined flint clay and, second, by a siliceous grog derived from mixture 7, in series I-A, ground to pass a 20-mesh sieve but not separated further. The compositions of this series are given in table 2.

TABLE 2.

| No. | Miss. bond clay. Per cent | Ky. ball clay. Per cent | Tenn. ball clay. Per cent | Fla. kaolin. Per cent | Ga. kaolin. Per cent | Chert 20-40- mesh. Per cent | Chert 40-80- mesh. Per cent | Chert through 80- mesh. Per cent | Calc. flint clay 20-40- mesh. Per cent | Calc. flint clay 40-80- mesh. Per cent | Calc. flint clay through 80, Per cent | Calc. chert body through 1A-7 20 mesh |
|-----|---------------------------------------|-------------------------------------|---------------------------------------|--------------------------------|-------------------------------|---|---|---|--|--|---|---|
| 1.. | 8.33 | 8.33 | 8.33 | 12.5 | 12.5 | 12 | 4.5 | 13.5 | 8 | 3 | 9 | .. |
| 2.. | 8.33 | 8.33 | 8.33 | 12.5 | 12.5 | 10 | 3.75 | 11.25 | 10 | 3.75 | 11.25 | .. |
| 3.. | 8.33 | 8.33 | 8.33 | 12.5 | 12.5 | 10 | 3.75 | 11.25 | .. | .... | ... | 25 |
| 4.. | 8.33 | 8.33 | 8.33 | 12.5 | 12.5 | .... | .... | ... | .. | .... | ... | 50 |
| 5.. | 8.33 | 8.33 | 8.33 | 12.5 | 12.5 | .... | .... | ... | 10 | 3.75 | 11.25 | 25 |
| | | | | | | | | | calc. flint clay, 8-20 mesh | | | |
| 6.. | 8.33 | 8.33 | 8.33 | 12.5 | 12.5 | 12.5 | 12.5 | ... | .. | 25 | ... | .. |

It will be noted that the combination of sizes of the chert and calcined flint clay which was previously fired to cone 13 is the same as for series I.

These pots came from the kiln in very good shape but all cracked in the heating and cooling tests. The cracks were very fine and in some cases had to be looked for very carefully, being almost hair lines. Body 6 had only a very minute crack and was probably the best mixture up to this point.

Series II-B

This series was an exact duplicate of series II-A except that gannister and the calcined gannister body IB-7 were substituted for chert and calcined chert body.

These specimens came from the kiln in very good shape but failed in the heating and cooling test, showing larger cracks than the pots of series II-A.

The fire shrinkage of the two series, II-A and II-B, were as follows:

| | | | | | |
|----------------------------|-----|-----|-----|-----|-----|
| II-A No. | 1 | 2 | 3 | 4 | 5 |
| Contraction, per cent..... | 3.1 | 3.7 | 1.8 | 2.5 | 3.7 |
| II-B No. | 1 | 2 | 3 | 4 | 5 |
| Contraction, per cent..... | 4.1 | 4.4 | 2.5 | 3.4 | 4.4 |

In this series, while there was an improvement in the resisting quality of the pots subjected to the heating and cooling tests, it is noted that even in bodies 5-A and 5-B, where the previously calcined siliceous material is reduced to 25 per cent, failure is met with, due perhaps to lack of fineness. Here again the gannister series shows cracking to a greater extent.

Series III

In this series it was decided to use a different combination of sizes for non-plastic materials and to replace the raw by calcined chert and gannister, previously fired to cone 14. It was found that the chert, although much easier to grind in the calcined state, still retained much of its former hardness. On the other hand, the calcined quartzite could be readily broken down into its individual grains, which passed the 40-mesh sieve. No attempt was made, therefore, to prepare this material in the coarser sizes

nor to separate it into definite proportions of the smaller sizes. The clay content and proportions remained the same as in series II.

Series III-A

The compositions of these mixtures are given in table 3.

TABLE 3

| No. | Clay, in proportion of series II. Per cent | Calcined flint clay 8-20-mesh. Per cent | Calcined flint clay through 20-mesh. Per cent | Calcined chert 8-20 mesh. Per cent | Calcined chert through 20-mesh. Per cent | Calcined chert through 40-mesh. Per cent |
|-----------|---|--|--|---------------------------------------|---|---|
| 1 | 50 | 25 | | 25 | . . . . | .. |
| 2 | 50 | 25 | | | | 25 |
| 3 | 50 | 25 | | | 25 | .. |
| 4 | 50 | 12.5 | 12.5 | 12.5 | 12.5 | .. |

The pots made from the mixtures of this series came from the kiln in satisfactory condition but appeared to be "punky" and did not ring when struck, with the exception of 2. All of these specimens stood the heating and cooling test, but since a compact and strong structure was desired the composition of 2 was taken as a basis for further work.

The firing shrinkage of the bodies of series III-A were found to be as follows:

| No. | 1 | 2 | 3 | 4 |
|------------------------------|-----|-----|-----|-----|
| Shrinkage, per cent. | 1.6 | 2.2 | 2.5 | 2.2 |

The use of gannister in the compositions of series III was restricted to one body of the composition:

| | Per cent |
|---|----------|
| Clay (as in series II) | 50 |
| Calcined flint clay, 8-20-mesh | 25 |
| Calcined gannister, through 40-mesh | 25 |

This pot stood the heating and cooling test satisfactorily and had a good appearance. In the load test, maintaining a pressure of 50 pounds per square inch and a maximum temperature of 1375° C., held for one hour, the pot fractured. The fusion test showed a softening point of cone 31.

It appears from the results obtained for series III that it is possible to use a moderate amount of chert by opening up the

body through the use of coarser grog. The introduction of fine siliceous material as in mixture 2 produces a body having a good ring and which stands the heating and cooling test. Since the one gannister mixture of this series in which fine grained calcined quartzite was used also stood the heating and cooling test, it seems necessary to conclude that in every case the silicious material must be fine, especially if a dense body containing larger amounts of siliceous material is to be produced.

The present work was concluded with the preparation of two bodies, *a* and *b*, consisting of a mixture of raw clay and calcined flint clay with calcined chert and gannister, respectively, which had the following compositions.

| Body. | Clay as in series II Per cent | Calcined flint clay, 8-20-mesh. Per cent | Calcined chert through 40-mesh. Per cent | Calcined gannister through 40-mesh. Per cent |
|----------------|-------------------------------------|--|--|--|
| <i>a</i> | 50 | 10 | 40 | .. |
| <i>b</i> | 50 | 10 | .. | 40 |

These pots when fired had a very good appearance, especially specimen *a*, which was entirely free from surface cracks and had a better ring than *b*. The linear fire shrinkage of the chert body was 1.25 per cent and that of the gannister body 2.2 per cent. In the heating and cooling test specimen *b* cracked while *a* did not.

Specimen *a* was subjected to the load test, in which the contraction was found to be 0.6 per cent in terms of the original height. It was found to show a crack, undoubtedly due to the severe treatment, consisting in rapid heating and cooling while under constraint.

These two bodies again show the advantage of chert over quartzite and the use of finer over coarser siliceous material. The tendency of composition *a* to crack in the load test should have led to the use of a smaller amount of fine chert and a larger of calcined flint clay, preferably finer in grain than that used. It should be expected that a mixture consisting of 50 per cent of raw clay, 20 per cent of calcined flint clay and 30 per cent of chert, through 40-mesh, raw or calcined, would give very good results in every respect. Time did not permit further work.

In addition to the tests already mentioned some of the pots from series I and II were re-fired a number of times. Thus

body 6 of series I-A and 1, 2, 3, 4 and 5 of series II-A were all sound when re-fired six times in the regular burns conducted in the work. Mixture 4, series II-B (quartzite), cracked in the second firing but 1 and 2, series II-B, were still sound after two firings.

Conclusions

It is evident that no sweeping conclusions can be drawn from the limited number of mixtures and specimens owing to the variables which creep into investigations of this kind, but it would seem that the following statements are warranted:

1. The use of chert yields more satisfactory results than that of quartzite.

2. Finer ground siliceous materials are more advantageous than coarser ones.

3. Previous calcination of the chert or quartzite improves the resulting bodies with reference to heating and cooling treatment.

4. The introduction of calcined flint clay improves the general character of such siliceous refractories and counteracts their tendency to spall.

5. A neutral condition of no shrinkage or expansion in firing requires the use of between 60-65 per cent of raw chert or quartzite.

6. It appears that the use of siliceous refractories for saggars and other purposes, especially with the addition of chert, is entirely feasible and that the resulting products can be made to combine excellent resistance to load conditions and permanence of volume with satisfactory behavior under conditions of heating and cooling. A mixture of 50 per cent of raw clays, corresponding approximately to the proportions used in this work, 20 per cent of calcined flint clay and 30 per cent of chert, raw or calcined and passing a 40-mesh sieve, is suggested. For each particular service there must be a definite limit for the addition of free silica which may be higher than that indicated in the present work, which covers a condition of severe use.

CERAMIC ABSTRACTS

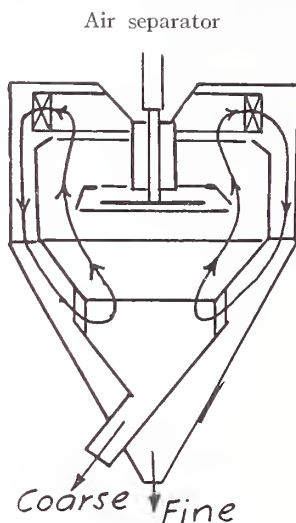
General

How a ceramic kiln may be insulated. P. A. BOECH. *Brick Clay Record*, 55, 1044-1047 (1919).—Ideal insulating material should possess the following properties: (1) Sufficient mechanical strength to resist wall strains due to expansion and contraction; (2) extremely high insulating value; (3) should not be decomposed or altered by high temperatures; (4) should be sufficiently refractory so as not to fuse or shrink when subjected to high heat, having approximately the same expansion as the brickwork; (5) light weight; (6) convenient form to be readily applied by unskilled labor; (7) low cost. The insulating material Sil-O-Cel is 25-30 lbs. per cubic foot naturally, or 8 lbs. per cubic foot for the loosely packed material. This material has best insulating properties when tamped to a density of about 15 lbs. per cubic foot. The melting point is 2930° F. (1610° C.). The internal conductivity varies between 0.5 and 0.8 B. t. u. per sq. ft. per hr. per degree Fahrenheit difference in temperature between ordinary temperature and 1800° F., being one-tenth that of high-grade fire brick between these temperatures. The insulating brick weigh about 1 $\frac{3}{4}$ lbs. each and have a crushing strength of over 400 lbs. per sq. in. For temperatures in excess of 1800-2000° F. it is desirable to use an insulating brick which has been kiln-burned to give it greater permanency in volume. These brick have a crushing strength of about 1200 lbs. per sq. in. but do not possess as good insulating value as the regular brick. Crowns can be best insulated with either a 2 $\frac{1}{2}$ or 4 $\frac{1}{2}$ inch course of insulating brick laid in a special mortar but not bonded to the brickwork of the crown. When kilns are unprotected they should be covered with one inch of insulating cement and then properly waterproofed with asphalt or another layer of brick. Insulator powder to a depth of 4-6 inches may be used in place of the brick, and this is then covered with an insulator cement. The side walls should contain a 4 $\frac{1}{2}$ inch thickness of the insulating brick, laid directly behind the 9-inch course of fire brick and the exterior brick. Considerable heat is lost through the base and foundation of the kiln. This can be reduced to a minimum by installing a thickness of 4 to 6 inches of insulating concrete directly underneath the fire brick bottom. The use of insulation has cut down radiation 50-75 per cent. The coal saved per year in a 30-foot kiln amounts to \$230 per year in some cases while the insulation costs only one-third of this.

H. G. SCHURECHT.

Air separator. *Keram. Rundschau*, 27, 295-296 (1919).—An air separator manufactured by the Pfeiffer Co., Germany, for 30 years was found to be an excellent substitute for screens and occupies only a small space. In this

separator no dust room is necessary for settling the dust as this takes place in the outer partition of the separator. The material is fed in the hopper (see diagram) from which it is thrown to the sides of the separator. Here it meets the upward current of air which takes the fine dust and tosses it to the



outer partition as the arrows in diagram indicate. Here the fine dust settles and the air returns to the inner chamber again, thus further separating the dust from the settling coarser material. For the extremely fine separation the dust from this first separator is run through another which has a series of plates between the distributor and the air current, which affect a more thorough separation.

H. G. SCHURECHT.

Patents

Tile-press. H. STOMMEL. U.S. 1,321,160, November 11, 1919. This is a power-operated dry-press. The pressing head is screw-operated, power being applied through vertical friction discs which operate either to raise or lower the head by contacting on opposite sides with the usual horizontally rotating flywheel. Leaf springs operate to check the upward movement of the head without jar. The bottom member of the die is fixed upon the usual table, the sides being movable relative thereto. In operation these latter members are raised and held in proper position by a spring. The material to be pressed is fed to the die in the usual manner and the pressing head lowered. When the head contacts with the side member of the die the supporting spring is released and the sides descend with the head. In order to discharge the side member is lowered below the bottom.

Briqueting-press. W. SCHUMACHER. U. S. 1,322,960, November 25, 1919. A power-operated lever press in which the sides of the die are slidable and the counterdie resiliently mounted.

Utilization of greensand. E. HART. U. S. 1,322,900, November 25, 1919. Greensand consists of ordinary silica sand coated with thin layers of glauconite. By tumbling the greensand in a tumbling barrel this glauconite can be removed and collected. Potassium alum can be formed by treating the glauconite with H_2SO_4 , about 66°Bé. , and allowing to stand, the acid reacting with the major portion of the iron, aluminium and potassium to form sulphates, heating to about 600°C. in a muffle, quenching the heated mass in water, keeping the mass wet for several weeks and lixiviating with hot water.

Treatment of greensand, marl and glauconite. E. HART. U. S. 1,323,228, November 25, 1919. The metallic oxides present are converted into chlorides in solution; an oxidizing agent added to convert ferrous chloride to ferric; the solution evaporated to dryness and heated to between 300° and 500°C. and then treated with steam to convert ferric chloride into oxide with liberation of HCl . The soluble chlorides remaining are dissolved and calcium and aluminium salts removed, leaving potassium chloride in solution. This may be concentrated and used as a crude fertilizer or in the preparation of pure compounds of potassium.

Method of treating potassium-bearing silicates. W. GLAESER. U. S. 1,323,464, December 2, 1919. A method treating potassium-bearing silicates to form water-soluble potassium salts. The silicates are heated at a low red heat, suddenly cooled, intimately mixed with pyrites and calcium sulphate, briquetted and exposed to air and moisture to oxidize the pyrites to ferric sulphate and then burned at above 900°C. in the presence of air and steam.

Recovery of potassium and aluminum compounds from greensand. M. HAUBER. U. S. 1,323,764, December 2, 1919. The greensand is intimately mixed with ferrous sulphate and heated at a dull red heat, thereby decomposing the ferrous sulphate and forming combined sulphates of potassium and aluminium.

Sound-record and process for making it. R. HEAD. U. S. 1,321,912, November 18, 1919. Fine modeling clay is substituted for the wax-like materials usually used in sound recording. When the record is made the clay is dry so that the groove made by the recording stylus may retain its exact configuration. After the record is made it is fired as pottery is fired. A metal matrix is made from this and the final records made as usual. The inventor states that instead of clay he may use plaster of Paris or a cement of a consistency and condition just about to set, the sound groove being formed just prior to the setting or hardening of the material.

Heat-conserving composition. M. EDLUND. U. S. 1,322,098, November 18, 1919. A composition consisting of clay, sawdust, cork, hair and shoddy.

G. E. MIDDLETON.

Refractories

The reversible expansion of refractory materials. J. W. COBB and H. J. HODSMAN. *Pottery Gaz.*, **501**, 1348-50 (1919).—The expansion of calcined alumina and silica bars were measured for comparison. For the alumina bar the expansion was found quite uniform with an increase in temperature, but for silica it was found to increase suddenly between 500°–600° C., due to a transformation of α -quartz into the β -quartz, and above this temperature it had practically no coefficient of expansion, and there was no inversion to trydimite. Tests on a clay showed a curve between that of alumina and silica with quite a rapid change in expansion in the neighborhood of 500° C., due to the silica in the clay. The coefficient of expansion of carborundum was very similar to that of fused alundum, while the expansion of magnesite was very high.

H. G. SCHURECHT.

Nova Scotia fire clays make good refractories. *Brick Clay Record*, **55**, 1037-38 (1919).—The fire clay described is on the island of Cape Breton, Nova Scotia. Two clays, one from Truro, N. S., and another from Sydney, N. S., are mixed together and make good refractories for coke oven walls, gas producer linings, and so forth. The chemical analyses are as follows:

| | 1 | 2 |
|---------------------|-------|-------|
| Organic matter..... | 7.76 | 4.46 |
| Silica..... | 71.48 | 79.56 |
| Alumina..... | 17.91 | 13.87 |
| Ferric oxide..... | 1.30 | 2.23 |
| Lime..... | .55 | Trace |
| Magnesia..... | Trace | Trace |

1. From Truro, N. S., and has a fusion point of 1670° C.
2. From Sydney, N. S., and has a fusion point of 1750° C.

H. G. SCHURECHT.

Some comparative tests of machine-made and hand-made silica brick. L. BRADSHAW and W. EMERY. *Pottery Gaz.*, **501**, 1338-39 (1919).—The conclusions arrived at by the authors are as follows: (1) The prevailing objections to machine-made silica brick appeared to be due to prejudice arising from early failures, due to improper mixing and using unsuitable machines; (2) in recent years the quality of machine-made silica brick has been greatly improved; (3) in no tests were the machine-made brick found inferior to the hand-made brick while in several important respects, *viz.*, the mechanical strength, resistance to spalling and abrasion and in accuracy of shape, they are superior to the hand-made brick.

H. G. SCHURECHT.

Specific heat of refractory materials at high temperatures. L. BRADSHAW and W. EMERY. *Pottery Gaz.*, **510**, 1338 (1919).—The specific heats of a number of refractories were determined at temperatures ranging from 600°–

1400° C. The method was to heat a weighed test piece of the material to the required temperature and then quickly drop it into a known weight of water and to measure the rise in temperature produced. Heating was done in an electric furnace placed vertically over the tank, which was surrounded by insulating material and enclosed in a wooden case. The results show that the specific heats of materials increased at high temperatures, the increase in the case of fire clay and silica brick between 100° and 1400° C. being approximately 50 per cent. This means that the amount of heat required to raise the temperature of a given weight of material through an interval of 100° C. from 1200° to 1300° C. was greater than that required to raise the temperature from 100° to 200° C.

H. G. SCHURECHT.

Refractories in the zinc industry. J. A. AUDLEY. *Trans. Ceram. Soc. (Eng.)*, 18, 43-66 (1919).—The retorts or muffles are made of a mixture of raw fire clay and burned clay or clean fragments of old retorts; the mixture is more resistant to fluxes the higher the ratio of alumina to silica, and accordingly the addition of coarse-grained quartz (as in Upper Silesia) to the retort mixture has not proved successful with basic charges. The great objection to the ordinary mixtures is that clay is a bad conductor of heat, and will not stand great fluctuations in temperature, that it is attacked by material in the charge, and that its porosity allows zinc vapor to escape. The chief requirements of a zinc retort include refractoriness, resistance to dust and slag, mechanical strength and tenacity, resistance to sudden temperature changes, low degree of permeability to zinc vapors, minimum contraction in the fire, and durability. In practice great influence is exercised by the process of preparing the mixture. In Silesia the mixture is composed of two volumes of raw rich clay (Briesen, Saarau, or Striegau, or mixtures of these), one of raw sandy clay (Striegau clay, or Silesian kaolin, or mixtures), and five of other materials. The latter are powdered fragments of old retorts and burned Neurode shale, mixed in different proportions. The size of the clay grains is from $1/25$ to $3/25$ inch in diameter. The larger pieces increase the strength of the muffle and make it more resistant to temperature changes and chemical erosion. In Belgium the proportions vary much. In some works 40 volumes of rich raw clay, 50 of burned clay, and 10 of coke are used. In other works the corresponding figures are 36, 54, and 10, respectively, and in still other cases the proportions are 30 of rich raw clay, 10 of sandy clay, 50 of retort fragments, and 10 of coke. Another Belgian composition is 10 of raw clay, 10 of burned clay, 8 of retort fragments, one of quartz, and 0.5 of coke. Coke added to the mixture for making retorts or muffles, improves the refractory qualities of clay and reduces shrinkage. In Belgium and Westphalia the retorts are often glazed externally in order to render their sides impervious to zinc vapor. In many Belgian works, and in Spain, much quartz or sand is added to highly siliceous clay, so that the retorts consist chiefly of silica, which stands fire well, is a good conductor of heat, and enables thinner vessels to be made, but it is certainly less resistant than alumina to fluxes, though not so much corroded by

siliceous ores. These retorts are often also glazed. The condensers are made of less refractory materials than the distillation vessels. In many places they are made of equal parts of raw and burned clay, or of ordinary clay mixed with ground retort fragments and coke or coal ash.

The walls of new retorts absorb zinc at first, forming zinc aluminate (artificial zinc spinel), which gives the well-known blue color. The average zinc content of old retorts is 6 per cent, but may rise to as much as 21 per cent, as at the Bethlehem Zinc Works, Pennsylvania; in seven samples of broken retorts from Upper Silesia the average amount of metallic zinc was 12.87 per cent. The addition of coke to the retort material, and the employment of heavy pressure in making the retorts, has resulted in greatly reducing the absorption of zinc. The fine dust from the coal (consisting of silica, clay substance, iron oxide or pyrites, lime, magnesia and alkalies), attacks the clay substance of the porous vessels, forming a gradually thickening glaze. The zinc vapors in the meantime will change the clay substance into zinc aluminate (zinc spinel), the silica—both that from the clay substance and quartz grains in the clay—being partly transformed into tridymite. The zinc spinel is formed particularly during the first time of using the vessels, while zinc vapors and combustion gases can diffuse readily through the retort before the coating of glaze is formed. Thus, after being in use a few days, the retorts do not consist of fire clay, but mostly of zinc spinel and tridymite. A zinc retort is thus a porous vessel, more or less damaged by various cracks, mainly consisting of clay substance, zinc spinel, and quartz or tridymite, with modifications in parts through local vitrification. In the zinc furnace the vessel can resist powerful mechanical influences, because the fired body, though brittle when cold, has great tenacity in the white hot state. The degree of impermeability to zinc vapors depends largely on the kind and number of external and internal surface cracks, and on the density and viscosity of the glaze. The use of magnesia for retorts has proved unsatisfactory. Coatings of graphite and clay and of fused bauxite and zirconia are suggested.

A. J. LAMBERT.

Patents

Refractory cement. H. B. BOOTH. U. S. 1,321,085, November 11, 1919. This cement is designed particularly for protectively coating electrodes. It consists of feldspar 15–40 per cent, artificially crushed quartz 40–20 per cent, silica sand 15 per cent, and 30–15 per cent of a binder consisting of sodium silicate 92 parts, sodium sulphate 8 parts, and water. The feldspar content is varied, depending upon the heat. For an electrode heating to 3000° F., 15 per cent feldspar, 40 per cent crushed quartz is used, while for an electrode heating to 1500° F. 40 per cent feldspar, 20 per cent crushed quartz is preferred.

G. E. MIDDLETON.

Enamels

Materials and methods used in the manufacture of enameled cast iron wares. HOMER F. STALEY. U. S. Bur. of Standards *Tech. Paper* 142.—This

is a comprehensive treatise dealing with the various phases of the technology of manufacturing enameled cast iron wares. It is the first publication dealing fully with this subject in any language.

The paper deals particularly with the coating of cast iron with white vitreous enamels by the American or dry-powder process. In this method of manufacture, the thoroughly cleaned castings are painted with a suspension in water of powdered glass, clay and other materials. This suspension is known as the ground coat. The castings are then heated until the ground coat is thoroughly fused, forming an extremely thin layer of transparent glass on the castings. The ware is then withdrawn from the furnace, and immediately coated by means of long-handled sieves with a layer of white, opaque, powdered glass, known as the cover coat enamel. Next the castings are returned to the furnace, and in a couple of minutes the cover coat enamel fuses to a smooth layer. Two such layers of cover coat enamel are usually applied, giving a total thickness of from $\frac{1}{32}$ to $\frac{1}{16}$ of an inch. The paper does not discuss the enameling of cast iron with wet coat cover enamels.

Several sections are devoted to a discussion of the preparation and testing of the various chemicals and minerals used in compounding enamels and to the effect each of these has on the physical and chemical properties of enamels. The methods employed in making and cleaning the castings are described in detail, beginning with construction of patterns and ending with sand blasting and polishing. The methods and equipment, including furnaces, used in preparing enamels and applying them to castings are covered in two sections.

Sections are devoted to the control of the luster of enamels, the cause and control of crazing, and to the methods to be used in avoiding blisters, pin holes and other minor defects. Typical formulas are given for ground coat enamels, cover coat enamels containing oxide of tin, and for those containing antimony compounds as the opacifying agent. These formulas are each stated in terms of raw batch for 1000 pounds melted enamel, of percentage composition and of empirical chemical formula. The calculations involved in arriving at each form of expression are explained in detail.

R. R. DANIELSON.

Fuel consumption of muffle kilns in the enameling industry. L. VIELHABER. *Keram. Rundschau*, 27, 293-294 (1919).—The question whether producer-gas fired kilns are better than semi-gas fired kilns in the enameling industry is important to those installing new kilns. It is admitted that the producer-gas ovens are successful in many metallurgical industries and will be important for the larger enamelware companies, but it is doubtful whether they are much better than the semi-gas fired kilns now used extensively in Germany for small plants. A heat balance was run on an enamel muffle-oven which in 24 hours burns 1800 kg. of ware and 500 kg. of coal. The calculations were as follows:

Specific heat of enamel and iron = 0.15.

Melting point of enamel = 950° C.

Heat used in heating enamel and iron = 0.15×1800

$\times 950$ 256,500 heat units

Heat of fusion of enamel = 70 heat units.

540 kg. of the 1800 kg. of ware is enamel, hence heat

used in melting enamel = 70×540 37,800 heat units

Heat used 294,300 heat units

Heat lost through opening of doors = $24 \times 15 \times$

2640 950,000 heat units

Since doors are opened 15 times per hour, through which the temperature drops 30° C.

The muffle has a volume of 0.224 cbm. of fire brick which weigh about 400 kg.

The specific heat of the brick is 0.22 and hence to heat 400 kg. to 30° C., $0.22 \times 30 \times 400 = 2640$ heat units are used.

The producer gas is heated to 450° C. One kg. of coal produces 12.8 cbm. of gas, which has a value of 6592 heat units. In 24 hours $500 \times 6592 = 3,296,000$ heat units are given up by the gas.

Theoretical air necessary = 6.04 kg.

Practical air necessary = 8.45 kg.

Excess air = 2.41 kg.

Theoretical products of combustion = 11.45 kg.

Products of combustion from 1 kg. coal = 13.86 kg. or 6930 kg. for 500 kg.

Since gases leave recuperator at 500° C., the following heat is lost in the smoke-stack: $0.255 \times 500 \times 6930 = 883,575$ heat units.

Heating enamel 256,500 heat units

Melting enamel 37,800 heat units

Radiation loss 1,186,560 heat units

Lost through opening doors 950,000 heat units

Lost through chimney 883,575 heat units

3,314,435 heat units

If the gas passes to recuperator at 800° C. we get:

$0.255 \times 800 \times 6930$ 1,413,720 heat units

Heat passing through chimney 883,775 heat units

Saved by recuperator 529,945 heat units

If air in recuperator is heated to 490° C., 520,240 heat units are saved by the recuperator, or 76 kg. of coal are saved per 24 hours.

Heat used is as follows:

Enamel heating 256,500 heat units

Heat of fusion 37,800 heat units

294,300 heat units

Converting coal in generators to gas also requires heat, the coal having a heating value of 7530 and the gas from 1 kg. of coal 6592 heat units, so 939 heat units are used in converting 1 kg. of coal to gas, or 469,800 heat units for 500 kg. Judging from these results the author believes that the semi-gas fired kilns with a small recuperator would give results very similar to the above.

H. G. SCHURECHT.

Patents

Rheostat. L. KEBLER. U. S. 1,321,104, November 11, 1919. A ground coat and a glaze are applied to the cast iron base and fired. A second ground coat and glaze are then applied upon this and the whole fired. The resistance elements are placed upon this second glaze surface, covered with a third glaze or enamel and the whole again fired. With the interposed relatively infusible ground coats there is no danger of the resistance elements sinking through the glaze and contacting with the base during the final firing.

G. E. MIDDLETON.

Whiteware and Porcelain

The gelatinization of clay-casting slip. J. W. MELLOR. *Pottery Gazz.*, 510, 1338 (1919).—When sodium silicate was used in casting slips it was noted that the slip gelatinized or became slimy, usually on the surface. Works in some districts were troubled with this more than plants in other districts. This may be due to the action of CO₂ in the air on the slip, which tends to coagulate it. Lime in water in the form of the acid carbonate may also coagulate the slip, so experiments were made in purifying water and comparing same with the unpurified tap water. It was found that water purified by the "Permutit" process permitted one to prepare a slip with a greater weight per pint and with a less percent of soda than was the case when the impure tap water was used.

H. G. SCHURECHT.

Patents

Kiln car. J. B. OWENS. U. S. 1,321,388, November 11, 1919. This car is designed particularly for use in an Owens tunnel kiln. Its frame is a unitary cast iron structure carrying a platform of fire brick. Each frame is provided with an integral projecting bumper which contacts with the adjoining car at its center. By thus applying the pushing pressure at one central point, warping of the car frames does not result in the jamming of the whole train. There is a tongue and groove connection at the adjoining ends of the frames.

G. E. MIDDLETON.

Glass

Patents

Glass-drawing tank. W. A. JONES. U. S. 1,321,752, November 11, 1919. A buoyant division wall between twin glass tanks is provided. By extending only a short distance down into the molten glass it does not interfere with a free flow thereof, but it does prevent a free sweep of the flames from one tank to the other.

Glass-drawing bait. G. C. DEBAY. U. S. 1,321,810, November 18, 1919. As the drawn cylinder is swung into horizontal position preparatory to splitting and cutting, the blowpipe is automatically released from the bait. This relieves the cylinder from the weight of the blowpipe and prevents the cracking which often results because of this weight.

Mold-loading device. R. E. McCAULEY. U. S. 1,322,318, November 18, 1919. The glass furnace is provided with an extension into which flows the glass to be dispensed. An aperture is provided in the lower part of this extension and a tubular member connected with a vent and a suction pipe is provided in the extension above the aperture. By reducing the air pressure in the tubular member, glass is drawn upwardly therein and prevented from discharging through the aperture. The pressure is then allowed to return to normal and the column of glass descends, passes out through the aperture and into a mold positioned to receive it.

Glass-gathering and blowing machine. M. J. OWENS. U. S. 1,322,726, November 25, 1919. This invention is designed as an improvement to the "Owens" bottle machine. In that machine a rotary frame carries a series of blank molds over a pool of glass, the glass is sucked up through the bottom of the mold, the glass in the mold severed from that in the tank, the blank is blown in the blank mold, the knife is withdrawn leaving the blank suspended from the neck mold, the blow mold is then placed in position and the final blowing effected. The present machine employs a pneumatically operated plunger which serves as a support for the blank after the immediate withdrawal of the knife, as well as a bottom for both blank and blow molds. When the blank mold is removed the blank remains positioned upon this support and not suspended from the neck mold as formerly.

Glass-annealing oven. W. STENDER. U. S. 1,322,735, November 25, 1919. The annealing bed is intermittently moved through the oven. At the feed end of the oven, a semi-circular article supporting plate is supported immediately above the bed. An annular feed device provided with peripheral pockets rotates above the supporting plate and positions articles to be annealed thereupon as they are fed from the molding machine. When the supporting plate is filled, the articles are automatically swept off upon the annealing bed which then moves forward another step.

Glass-furnace. H. E. DEVAUGHN. U. S. 1,322,767, November 25, 1919. In the operation of glass-furnaces, the piers built up from the bottom or from the walls to support the cap of the furnace and to separate the drawing chambers, are frequently destroyed by the molten glass. This is obviated by suspending the skew blocks and the furnace cap over the tank or furnace. Means are provided for protecting the suspension devices from the intense heat.

Vial-necking machine. W. D. FREDRICK, W. E. GLASPEY and C. F. COX. U. S. 1,322,778, November 25, 1919. Small glass bottles or vials are made from previously formed glass tubes by cutting to proper length and then forming bottom and neck. This operation is usually performed by hand. This machine forms the neck automatically, the operation being performed simultaneously upon both ends of a blank, and from the partly finished blank so prepared two vials may be produced, such blank being separated intermediate its ends and the two sections separately bottomed by the machine shown in U. S. 1,322,779.

Vial-bottoming machine. W. D. FREDRICK and W. E. GLASPEY. U. S. 1,322,779, November 25, 1919. The double-necked blank formed in the machine shown in U. S. 1,322,778 is intensely heated at its middle, stretched to breaking and then both bottoms thus formed flattened by being pressed against an interposed double-ended anvil.

Method and apparatus for drawing wire glass. I. W. COLBURN. U. S. 1,323,389, December 2, 1919. Wire cloth passes around a roller slightly immersed in a tank of molten glass and passes off horizontally embedded in a sheet of glass. It then passes between cooling rolls.

Process and apparatus for feeding molten glass. B. D. CHAMBERLIN. U. S. 1,323,450, December 2, 1919. The glass after passing the discharge orifice passes through a heated tube of larger diameter than the glass stream and terminating in a water-cooled shearing edge. Beneath this is situated an intermittently rotating, combined receiving and shearing member. When the upper pocket of this member has received the proper quantity of glass the member is rotated through 180° , shearing the glass stream, depositing the glass charge in a mold positioned below and presenting its other pocket for the reception of further glass.

Glass-mold charging apparatus. F. L. O. WADSWORTH. U. S. 1,323,507, December 2, 1919. A stream of molten glass flows from the tank into a mold beneath the orifice. When the proper amount of glass has entered the mold, the stream is sheared by two approaching blades situated immediately beneath the orifice, forming, when in contact, a V-shaped trough which momentarily supports the glass. A two-part intermediate supporting cup is then shifted into place beneath the shearing blades which are then separated, allowing the glass to flow into the supporting cup. Meanwhile an empty mold is moved into position, the supporting cup is opened and the glass allowed to flow into the mold.

Cement and Lime

Preheating air for rotary kilns. S. H. HARRISON. *Concrete* (Cement Mill Section), 16, 9 (1920).—It has been shown that about 11 per cent of the heat applied to a rotary kiln in the burning of Portland cement remains in the hot

clinker as it leaves the kiln. One of the most practical methods of reducing this loss is to utilize the heat of the clinker to preheat the air necessary to support the combustion of the coal in the kiln. It is necessary to control the amount of air allowed to pass through the clinker cooler into the kiln so that there will not be too great an excess of air. The clinker leaves the kiln at a temperature of about 1200° C. and gives up to the air approximately 520 B. t. u. per pound of clinker. Assuming that the theoretical amount of air for complete combustion of the coal enters the cooler at atmospheric pressure it is calculated that 480° C. is the maximum temperature to which the air is, heated. Curves are given showing the relation between the temperature of the preheated air and the weight of coal per pound of clinker, for amounts of excess air from 50 to -10 per cent. The highest theoretical temperatures are obtained when the fuel consumption is lowest. There should be a slight excess of air rather than a deficiency, in order to obtain the highest kiln efficiency.

F. A. KIRKPATRICK.

New wet process plant of the Indiana Portland Cement Co. STAFF ARTICLE. *Concrete* (Cement Mill Section), 16, 1 (1920).—The plant is located near Greencastle, Ind. Reinforced concrete is the material used for construction of buildings, tanks, piers, and so forth. The storage pits are of the following capacity in tons: Limestone 5,600, shale 1,600, clay 1,500, clinker 41,000, gypsum 580, coal 1,400. Raw materials are hauled in 3½-yard dump cars to the storage bins. The clay is mixed with 60 per cent of water and reduced to a slurry in a specially designed disintegrator 20 feet in diameter and 6 feet deep. The dry crushed limestone and shale are run into the clay slurry, the mixture having from 30 to 36 per cent water. The slurry is then passed over screens having openings of 0.049 inch and then ground in a tube mill until 88 per cent passes a 200-mesh sieve. It is then run into three correcting basins each 18 feet in diameter and 10 feet deep, and from these into a mixing basin of 1200 barrels capacity. It is then lifted by a compressed air lift into a storage tank above the kiln. This kiln is 10 feet in diameter and 240 feet long, lined with Louisville fire brick for 210 feet, and lifter plates fastened to the upper 30 feet stir the slurry to bring it into contact with the hot gases. The clinker passes into a rotary cooler 7 feet by 66 feet, containing lifter plates to stir up the clinker and with a specially designed fan at the lower end. The clinker drops from the cooler into storage, from where it is taken by crane as required for grinding. Reduction is accomplished in two steps, first to 65 per cent of 100-mesh size in a comminutor, then to flour in a tube mill. The fuel is powdered coal. The coal is passed through a Cumber dryer, then ground in Fuller mills. Detailed layout of the plant and a number of photographs are given.

F. A. KIRKPATRICK.

Patent

Utilization of low-grade carboniferous material in the manufacture of Portland cement. R. W. LESLEY. U. S. 1,323,294, December 2, 1919. Low-grade carboniferous materials such as oil shale, lignite and low-grade

bituminous and cannel coal are heated to drive off their volatile constituents, leaving an argillaceous residue and fixed carbon. This residue is mixed with calcareous material and charged into a rotary cement kiln. The volatile constituents first driven off as stated above, together with the fixed carbon in the residue, serve as fuel. The hot gases given off during this clinkering operation are used in the initial process of driving off the volatiles. Thus is secured a self-contained process of forming Portland cement clinker.

U. S. 1,323,293 is drawn to the apparatus used in carrying out the above process.

Process of making cement. H. D. BAYLOR. U. S. 1,323,952, December 2, 1919. Cement is made slow-setting and plastic by adding CaO thereto, comminuting the mass, adding oily or waxy material and simultaneously stirring in the presence of an amount of water sufficient to hydrate all the CaO, and finally grinding.

Cement composition. J. GAISSE. U. S. 1,322,893, November 25, 1919. A plastic composition consisting of approximately 10 parts of superfine cement, 4 parts hydrated lime, 2 parts marble dust and water.

G. E. MIDDLETON.

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

December 29, 1919. It was voted to print the standard clay tests proposed by the Committee on Standards and submit them to the voting members for adoption.

January 13, 1920. It was voted to appoint Mr. H. F. Staley, Editor of the JOURNAL, in place of Mr. G. H. Brown, resigned.

February 2, 1920. It was voted that the American Ceramic Society become a member of the International Chemical Union, thus becoming entitled to the publications issued and the recognition accorded members of this association and that the Society authorize the annual payment of the fees of approximately the amount stated, a sum not to exceed \$40 per year.

New Members Received during January

Resident Associate

Blanchard, C. R., General Electric Co., Pittsfield, Mass.

Brenner, R. F., Chief Chemist, Bartlett-Collins Glass Co., Sapulpa, Okla.

Brett, R. C., Southern Clay Mfg. Co., North Birmingham, Ala.

Burdick, Percy W., Ceramic Chemist, Carborundum Co., Niagara Falls, N. Y.

Burgess, M. L., Secretary-Treasurer, Marietta Mfg. Co., Indianapolis, Ind.

Healey, A. S., Superintendent, Standard Sanitary Pottery Co., Elizabeth, N. J.

Hibbs, Jos. S., Assistant General Manager, J. W. Paxson Co., Philadelphia, Pa.

Leibson, J. S., General Electric Co., Schenectady, N. Y.

Lintz, E. H., Jewett Refrigerator Co., Lackawanna, N. Y.

Menne, L. H., Enameler, Theo. A. Kochs Co., Chicago, Ill.

Morey, Geo. W., General Manager and Scientific Director, Spencer Lens Co., Hamburg, N. Y.

Palmer, Ralph M., E. I. du Pont de Nemours & Co., Wilmington, Del.

Payne, A. R., Chief Physicist, Hazel-Atlas Glass Co., Clarksburg, W. Va.

Stone, Charles H., Jr., Research and Industrial Chemist, Kemet Laboratories Co., Cleveland, Ohio.

Wiester, Stefan, Enameler, Malleable Iron Range Co., Beaver Dam, Wis.

Wright, Harry E., Superintendent, Kokomo Opalescent Glass Co., Clarksburg, W. Va.

Foreign Associate

Musiol, Charles, 16 rue de la Bigorne, Brussels, Belgium.

Saxton, Clement, Assistant Manager, Les Verreries, Aigues Mortes (Gard), France.

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EDITORIALS

RESEARCH AS AN INVESTMENT

One notable result of the European War has been the marked change in the status of industrial research in this country. Before the war research was looked upon as an interesting side-issue of academic life, very indirectly related to factory management, but from the financial standpoint to be considered a non-essential luxury. During the war, the value and necessity of research were well proven, and consequently it has received a tremendous amount of advertising. To-day industrial research is not only respected; it has reached the enviable, but precarious, position of being a fashionable investment. Almost every day we hear of some trade organization or large industrial corporation that is anxious to invest a considerable sum in research. The money is available; the question is how shall it be invested wisely? This question is of considerable importance both to the investors and to all who are interested in the development of research. A few unwise and unprofitable investments at this time will give a decided set-back to the growth of industrial research in this country.

Conservative investment in research, like investment in land or stocks and bonds, must be a matter of detail. It is necessary to invest in definite researches. Many firms and associations which are attempting to invest in research generally, by establishing laboratories and hiring staffs of investigators, without having a definite research program, will be simply lucky if their investments prove profitable. Their chances for financial returns lie in the facts that the field for research is so broad, the

possible applications of results obtained are so varied, and the financial returns from even one successful application are so great that even ill advised and poorly directed researches, amply financed and persistently conducted, may yield large profits. The undertaking of research on such a plan by an organization with limited financial resources must be considered as speculation. When undertaken as a long-time project by an organization with abundant resources and with staying power it becomes investment.

The first step in conservative investment in industrial research is to make a survey of the field and to decide just what researches shall be undertaken. Of course, experts should be asked to make this survey; and these should be of two types, the engineering and the scientific. Engineers, thoroughly experienced in the particular industry in question, can tell just what is known about the subject and the possibility of improvement by the efficient application of this knowledge or moderate extension of it. It is surprising how often researches are conducted for the purpose of improving methods of manufacture when what is really needed is better engineering and factory management. On the other hand, it is the special function of scientists to tell of the possibilities of development by researches based on theoretical considerations.

For conducting researches two general methods are available, the empiric, or engineering, and the theoretical, or scientific. The empiric method is ordinarily used by engineers in conducting investigations. As is well known it consists in starting without any theory and by empiric trials collecting data for use in deriving an engineering formula or the basis of a new process of manufacture. In the scientific method, the investigator starts with a theory and conducts investigations to see whether the theory is applicable. Of course, engineers sometimes use the scientific method and scientists the theoretical one; but the use of the empiric method by engineers and the theoretical method by scientists is rather characteristic. In some quarters there is a tendency to decry the use of the empiric method in research, but it has been and will remain an important factor in the development of all industries. Most of the researches reported in the publications of this Society are of the empiric type.

Empiric researches usually keep close to established engineering practice and are rather more certain to yield usable results than theoretical researches. On the other hand, these results are not as spectacular and revolutionary in their effects as the results of the occasional successful research based on theory. As investments empiric researches may be considered as safe; but, like all safe investments, they yield a comparatively moderate return on the money invested. Researches based on theory must be considered more hazardous investments, but they yield large returns if successful.

As to the men to be chosen for actually conducting researches, we may say that there is no such thing as an ideal research man. An efficient research staff must consist of at least two men, an engineer and a scientist—the engineer to get the work done, and the scientist to perceive and make use of the by-products of the investigation. The engineer is primarily a man of action. He sets himself a goal and works directly toward it; he gets the job done. Because of this directness of aim and concentration of effort he is very liable to overlook or neglect interesting and often potentially valuable facts that may come to light during the research. On the other hand, the typical scientist is a man of imagination and omnivorous curiosity. He is interested not only in arriving at a fixed goal but also in exploring all the by-paths leading off from the direct road. He loves not only to note directly useful data but also to allow his imagination to play with the possible utility and meaning of seemingly adventitious phenomena. Moreover, unlike the engineer, the scientist is not satisfied with finding one efficient way of doing a thing, but is interested in investigating all the refinements of the various possible ways. For these reasons scientists are slow in completing set tasks.

Therefore, in industrial research men of the engineering type should be employed for executing specific researches and scientists for assisting in planning investigations and for conserving the by-products of researches.

ORIGINAL PAPERS AND DISCUSSIONS

PRODUCER GAS AS FUEL FOR THE GLASS INDUSTRY

By F. J. DENK

The continuous decrease in the supply of natural gas, on the one hand, and the steady increase in the cost of coal on the other, has forced glass manufacturers to look for either a cheaper fuel or for a means to burn their present fuel in a more economical and more satisfactory way than before. The fuels at hand at the present time are natural gas, coal or coke and oil. The amount of natural gas available for the industries is declining rapidly. The cold spells we had this winter forced many a factory, which had to rely exclusively on natural gas as fuel, to shut down completely. The present price of coal is too high to allow coal to be wasted; but this is done as long as coal is burned in a direct-fired furnace, either using the coal as such, or having a gas producer built integral with or close to the furnace and using the producer gas without any regeneration. The same holds good for coke used directly in lehrs, glory-holes, and so forth. Oil, finally, is a very expensive fuel, at least in western Pennsylvania and eastern Ohio. In and around Pittsburgh, for instance the price of fuel oil was, before Christmas, $11\frac{3}{4}$ cents per gallon. This price corresponds (see figure 1) to about \$17.50 per ton of coal, figuring straight conversion with a 12,500 B. T. U. coal and 80 per cent furnace efficiency. Counting on about \$1.00 for fixed and overhead charges per ton, which is fairly high, still leaves a coal price of \$16.50 per ton. Since we can get, in many cases, coal for between \$3.00 and \$4.00 per ton delivered at the factory, it can easily be seen that a price of $11\frac{3}{4}$ cents per gallon of oil is prohibitive.

In the districts along the coast, where oil is comparatively cheap, conditions are somewhat different. But even there coal, costing, say, \$5.00 per ton, will give producer gas which can compete with oil at 4 cents per gallon. It is true, the first cost of an oil installation is cheaper than that for a producer gas installation. But this advantage is more than offset by the high operating cost. To illustrate this, I have calculated the first cost and the operating cost for an oil plant and for a gas producer plant, the latter for hand-poked producers and for mechanical

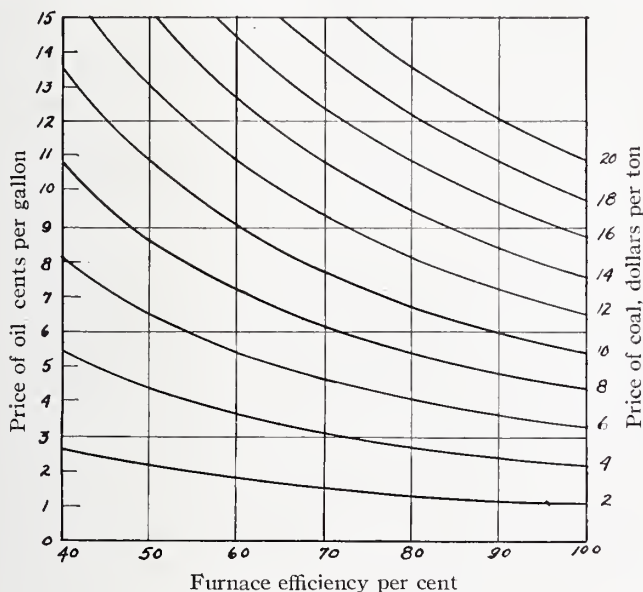


FIG. 1.—Equivalent price of oil in cents per gallon for different coal prices in dollars per ton and different furnace efficiencies.

Direct conversion; coal with 12,500 B. T. U. per pound.

producers. Basing the calculation on a daily consumption of 1,500,000 cu. ft. of natural gas, we get (see Appendix and the accompanying table) when figuring on $11\frac{3}{4}$ cents per gallon of oil and \$3.50 per ton of coal:

| | |
|-------------------------------------|----------|
| First cost of an oil plant..... | \$36,500 |
| First cost for a gas producer plant | |
| with hand-poked producers..... | \$46,500 |
| and with mechanical producers..... | \$65,500 |

The corresponding operating cost per day is then:

\$1409.40 for oil,

\$ 355.28 for hand-poked producers, and

\$ 340.11 for mechanical producers.

This shows, that, although the first cost of a gas producer plant with mechanical producers is about 80 per cent higher than the first cost of an oil plant, the operating expenses for such a plant are only about 24 per cent of the operating expenses of an oil plant. The equivalent cost of natural gas for the three installations in question is: 94 cents per 1000 cu. ft., 23.7 cents per 1000 cu. ft. and 22.7 cents per 1000 cu. ft., respectively. Oil, therefore, can compete in our case with artificial gas only, selling at \$1.00 per 1000 cu. ft.

Based on a daily consumption of 500,000 cu. ft. of natural gas, the first cost as well as the operating cost for the three installations will be smaller, but the equivalent cost of natural gas is about the same as above, *i. e.*, 95.8 cents per 1000 cu. ft., 26.2 cents per 1000 cu. ft. and 25.0 cents per 1000 cu. ft. We can see from these figures, that producer gas is the cheapest fuel, because there is no district in the East any more where natural gas is sold for industrial purposes for less than 30 cents per 1000 cu. ft.

Where the price for oil is small and that for coal high, the figures will tell a somewhat different story. The calculation, based on a cost of 4 cents per gallon for oil and of \$5.00 per ton for coal, give, for an assumed equivalent consumption of 1,500,000 cu. ft. of natural gas per day, the following equivalent values for natural gas: from oil 37.1 cents, from gas from hand-poked producers 30.1 cents, and from gas from mechanical producers 29.5 cents, all per 1000 cu. ft. The corresponding figures for the smaller plant are 40.0 cents, 33.7 cents and 32.6 cents, respectively. These figures show that with a decrease in the cost of oil and an increase in the cost of coal the difference in operating expenses between oil and producer gas plants will become less and, for a certain price for oil, a price for coal can be determined for which the operation of a producer gas installation would cost more than that of an oil installation. In our case this point would be reached, when coal is \$6.25 per ton, oil costing 4 cents per gallon.

The above proves that producer gas is, in most cases, the cheapest fuel for glass factories, no matter if it is generated in hand-poked producers or in automatic producers.

My experience has shown me that many of the men in charge of medium- or small-sized glass plants are not at all familiar with the application of producer gas. In many cases I have found that they are actually afraid to use it. It is hard for anyone, after having been accustomed to natural gas for all these years, to have now to resort to a fuel, quality and quantity of which seems to be beyond their control. It is true, natural gas is, or rather was, the most ideal fuel in existence, while producer gas is man's work with all the defects connected with it. But we might as well make up our mind that the times of the natural gas are passed, never to come back again. Compared with natural gas, producer gas is a good fuel, or, taking into account the loss in heating value of natural gas, due to the extraction of gasolene, it is even a better fuel than the present natural gas. All depends on the design of the plant and on the care with which producers, gas lines and furnaces are handled. Frequently, unsatisfactory working of the furnaces is blamed on the producer gas, while it is actually due to an improper design of the furnace itself or to carelessness in regard to the application of the gas; for it must be kept in mind that a furnace which is designed along the lines for burning natural gas, can not and will not burn producer gas efficiently and satisfactorily.

In the following is given an outline of the layout of a plant designed for producer gas and some data in regard to handling it:

Types of Producers

The first question that may arise when contemplating the installation of gas producers is: What type of producers should be selected? This depends, to a large extent, on local conditions, *i. e.*, on conditions prevailing in the factory under consideration. As the operating cost is practically the same for both types, the first cost is of considerable influence. If the men available for operating the producers are common laborers, there is no use for installing high-grade automatic producers. This would, be about as bad as giving a man, who has never run anything

else but a small steam engine, charge of a modern, high power gas engine. The result would be the same in both cases, the machinery would get out of order in a short time, thus causing trouble and expense to the management. On the other hand, where the manager is willing to pay the higher first cost and where a superintendent with technical experience can take charge of the producer plant, mechanical producers should be installed. Hand-poked producers, when handled right, will answer the purpose to a certain extent, but they are too much under the influence of the human element.

Charging a producer will change the composition of the gas, its quantity, pressure and temperature, that is, practically everything which is variable. Conditions can be improved by charging small quantities of coal in short intervals, but this is, in many cases, too much work for the gas maker, or better laborer. He rather dumps two hoppers full at once and then sits down for a half hour. This procedure is wrong; it will be made worse if two or three producers are charged at the same time. The influence of charging on the temperature of the gas leaving the producer can be seen from the curve, figure 2. The temperature drops about 500°F. in 5 minutes, and it takes about 15 minutes to come up to normal again. If there are 6 or 8 producers in a plant, this drop in temperature would not be noticed very much, if only one producer were charged at the time. But, on the other hand, if there are 6 producers, and 10 minutes would elapse between charging, one producer would be charged once an hour and that interval is too long. It is, therefore, necessary to charge two or three producers at the same time and, for this reason, the influence of the temperature drop will be noticed in the furnace. All this trouble can be eliminated through the installation of mechanical producers. Due to the continuous coal feed and the continuous ash removal, they furnish a gas of a more uniform quantity and quality, temperature and pressure, besides generating gas with a better heating value than gas made in hand-poked producers, while the influence of the human element is reduced to a minimum. The mechanical producer is, furthermore, a labor saver, where more than two units are installed; but it frequently saves labor with even two units. Need-

less to say, for all types of producers the best working conditions for the coal available should be determined, and the producers should then be operated accordingly.

Another advantage of mechanical producers over hand-poked producers, which came to the front during the last year and a half, is that they can gasify low grades of coal better than the other type. Formerly, and until the summer of 1917, the in-

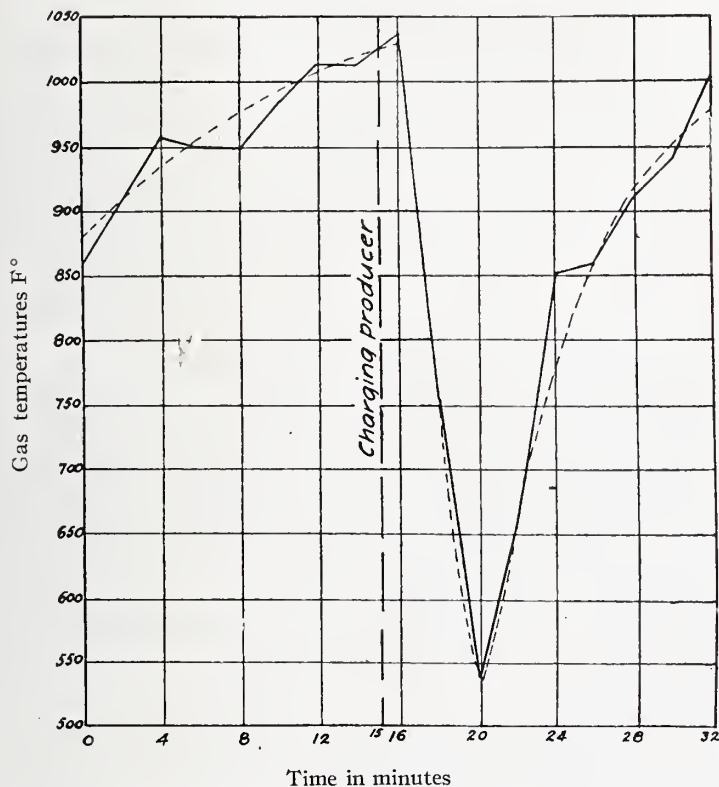


FIG. 2.—Curve showing influence of charging the producer on the temperature of the gas.

centive of competitive market conditions had maintained a practically uniform quality of the coal by special preparation. But from then on, the demand for coal was so insistent and the needs of the consumers were so pressing, that screening and washing

were largely abandoned; throughout the country the complaint was heard that coal was not being cleaned as in the past—that dirty coal was shipped. (U. S. Geol. Survey, Coal in 1917, part A, page 943.) I know this from my own experience to be true. According to the above statement, we now get a lower grade of coal than we used to get, and this lower grade is hard to gasify in hand-poked producers; but it can be gasified in mechanical producers. Taking, therefore, everything into account, it is the cheapest under present conditions to install mechanical producers and to employ men who know how to operate them.

The different types of the producers gasify different quantities of coal. As a rule, a stationary, hand-poked and hand-fed producer of 10 feet inside diameter can gasify between 900 and 1000 pounds of coal per hour, provided it is in good hands. Mechanical or automatic producers of the same size can gasify between 3000 and 3300 pounds of coal per hour, while the semi-automatic types can take care of about 2500 pounds. These are figures from good average practice.

Location and Layout of Producer Plant

The location of the producer plant in regard to the factory should be such that the bottom of the fuel bed in the producer is at a certain distance below the level of the ports in the furnace. The rising column of hot gases acts as a chimney. This point must be watched carefully, for, on account of the constant opening of the working doors of the furnace, the stack has no effect on the producer. If the producers are located too high, the gas cannot enter the furnace and trouble will result, unless special precautions are taken, which, in turn, may mean an increase in the first cost.

When hand-poked producers are installed, the layout of the producer plant should be designed in such a way that it will be possible to supply each unit in the factory with gas from a separate battery of producers. This means, for instance, a battery of producers for a pot furnace, a tank, a group of lehns, glory-holes, and so forth. The different batteries should, however, be cross-connected. It is not good practice to put up a number of producers and have them all feed into one main, from which the gas for the whole factory is taken. In such a case, if anything

happens to the gas main, the whole plant must be shut down, or if anything happens to one or two producers, the whole plant will suffer. But if each unit has its own battery and gas main, and the batteries are cross-connected, the arrangement will be flexible and an eventual partial breakdown of the producer plant will not be felt severely in the factory. The cross-connections should, of course, be closed during regular working conditions.

For mechanical producers, the arrangement should be the same in principle, although it may differ in detail from the one described before. On account of the high rate of gasification, a mechanical producer is able to supply gas to more than one unit. The layout, therefore, can be designed in such a way that the gas required by one unit and the necessary lehrs and glory-holes, or whatever other accessories may be depending on the working of the furnace or tank, can be generated in one producer of required size. But here again cross-connections should be provided to help along in case of an accident.

The above holds good, of course, in plants of larger size only, having several tanks or furnaces, or both; for small plants, which may need only one producer, it is well to have a spare producer, to be protected against an eventual breakdown of the producer in operation.

With automatic producers the operation is practically entirely dependent on the machinery, and the operators' attention should be directed mainly towards the upkeep of the mechanical parts. The personal equation, therefore, has not as much influence on the gasification of the coal as is the case with hand-poked producers, where it is a very important factor. For this reason a few words may be said about the operation of this type of producers.

Increasing the Efficiency of Producers

Conscientious and careful attention on the part of those in charge of the plant will increase the efficiencies of the producers. It is a well-established fact that poor results, obtained in one plant as compared with another, are often almost entirely due to carelessness. On the other hand, it must be borne in mind that sometimes conditions exist beyond the producers which materially alter the results. Especially should the gas lines have watch-

ful care, that dust accumulations do not obstruct pipes and valves. Cleaning attachments should be carefully located for the convenience and least labor of the attendants.

Simple water gauges will often be a useful guide, when registering the pressure of the gas at the outlet of the producer or on the system; this is especially necessary where an inspection is made only at irregular intervals. At the gas outlet the pressure should be between 1 and $1\frac{1}{2}$ inches of water column. In all cases, frequent analyses of the gas should be made, so that the factors governing the working of the producers can be determined and properly regulated. The amount of carbon dioxide (CO_2) in the gas should not be more than between 5 and 7 per cent.

It is not right to increase the gasification by simply opening the steam valve, thus increasing the pressure and the amount of steam blown. It is true, this will give more gas, but gas of inferior quality. The amount of steam blown should not be more than is required for preventing the formation of clinkers.

A thick fuel bed can be maintained, when the ash bed is kept low by cleaning out the producers in regular intervals. Cleaning should be done at least once a day; but if conditions demand, it should be done whenever necessary. The cleaning reduces the dead resistance in the ash bed, which acts against the entrance of the air, while the useful resistance in the fuel bed will be increased, allowing us to carry a thicker bed of incandescent fuel. The ash bed should be brought to a point 6 or 7 inches above the top of the blast hood and should at no time approach nearer. Neglect of this precaution may cause the loss of the blast hood. The thickness of the fuel bed should be between 2 and 3 feet.

Among the most common sources of trouble in the operation of hand-poked producer are irregular charging and neglect of the operator to close up the channels, which permit air to ascend freely and which are sure to form in the fuel bed of hand-poked producers. The air, thus admitted to the top, will cause the gases to burn within the producers, making lean gas for the furnaces. The same result will be produced by too thin a fuel bed, which also will allow the air to pass through and combine

with the combustibles in the producer gas instead of with the combustibles in the coal.

The gas lines must be of ample size to enable the gas to reach its destination without serious obstructions. On the other hand, the diameter must not be made too large, as this will retard the velocity of the gas. Near the producers and wherever there is a change in the direction of the flow, dust catchers must be provided to take care of the soot, which will be deposited at those places. Soot will always be in the gas, but a gas maker who understands his business will see to it that he gets as little of it as possible. I have seen gas lines which were clogged up in three days to such an extent that no gas could pass through them at all; and I have seen other ones where a blowing out every noon removed all the soot that was in them and that amounted to only a wheelbarrow full for each producer.

A procedure very often resorted to for cleaning the lines is "burning out." This procedure, in my opinion, is wrong, as it will damage the lines; besides, it is not necessary. If the gas is made right, the amount of soot will be small; and if the lines are designed right, this small amount of soot will be deposited in the dust catchers. Whatever little quantities will settle in the lines can be blown out once a day, thus eliminating all burning out of the gas mains. The blowing should be done by means of air rather than by steam. When steam is used, it will, with the soot and tar, form a solid cake in the lines, which is hard to remove. With air this trouble is eliminated.

The question of overhead or underground gas lines depends on local conditions. As a rule, an underground line is cheaper than an overhead line of the same capacity. The underground line has the further advantage that it does not allow the gas to cool as rapidly as an overhead line, which is exposed to atmospheric influences. Temperature readings taken on an overhead line of 150 feet length showed a maximum difference of 500° F between the producer and the furnace, while on an underground line of not quite 100 feet length this difference amounted to only 60° F. If conditions do not allow the putting in of an underground line, the location of the producer plant in regard to the factory should be such that the overhead lines will be as

short as possible. This must be done to save a considerable part of the sensible heat in the gas. If the lines are built according to the rules laid down above, there will be no reason why the factory should not always get enough gas, provided the producers are well taken care of.

Regenerating Chambers

The gas is to be used in furnaces and tanks after regeneration and directly in lehrs, glory-holes, flattening furnaces, etc. The regeneration takes place in the checker chambers. These chambers, therefore, form a very important part of the furnaces and tanks. I have stated in the beginning that direct-fired furnaces, when using coal, either as such or in a producer built near the furnace or forming an integral part of it, are wasteful. Notwithstanding this fact, furnaces with a direct coal fire are still in use and some have lately been designed and built for producer gas without regenerating chambers. It is true, a furnace will work under these conditions, as the gas comes in hot, having no chance to lose its sensible heat, and thus gives, even with cold air, the necessary temperature of combustion. But the saving in first cost, due to the elimination of the checker chambers, is more than offset by the higher operating cost and the less satisfactory working of the furnace. I will show, in one example, the difference in coal consumption for a furnace which was first operated direct with producer gas but which later was changed for regenerating the gas. For the direct firing, three 8-foot producers were required to furnish the gas, gasifying between 14 and 15 tons of coal per 24 hours. The producers had to be poked heavily all the time. After the furnace had been changed, only two 8-foot producers were necessary, gasifying a maximum of 8 tons per 24 hours total. This shows plainly the saving effected by a regenerative furnace. A direct-fired producer-gas furnace will work—there is no doubt about that—but with how high an expense and with how much trouble? That is the question which must be taken into consideration seriously.

In a direct-fired furnace, working with a temperature of about 2650° F, there is a maximum heat utilization of only 30 per cent. The installation of regenerating chambers increases this heat utilization considerably, and many a furnace builder guarantees

to the glass industry a saving of fuel of 60 per cent, which is not excessive. The difference in coal consumption for different types of glass furnaces may be seen from the data below:

A direct-fired furnace, without any regenerating chambers, uses from 2 to $2\frac{1}{2}$ pounds of coal for every pound of glass melted. This figure is reduced to the equivalent of $\frac{1}{2}$ to $\frac{3}{4}$ pound of coal for every pound of glass in a furnace fired with natural gas, having single regeneration only, that means, having only regenerating chambers for the air. In producer gas-fired furnaces I have seen coal consumptions of $\frac{1}{3}$ pound of coal per pound of glass, the furnaces having double regeneration, preheating the air and the gas. This last figure is not taken from a "show test," but from daily record sheets.

The checker chambers have to answer a two-fold purpose. In the first place, they have to serve as a means to transmit the surplus heat from the waste gases to the incoming gas and air, in order to enable these agents to generate the necessary heat in the furnace. But they must provide also an easy passage for the incoming gas and air and for the outgoing waste gases, without which easy passage it is not possible to operate the furnace and tank satisfactorily and efficiently. This second purpose has too often been neglected, with the result that the life of the furnace has been shortened to a considerable extent. It must, however, be kept in mind that it is not possible to build the checker chambers in such a way that they will serve both purposes simultaneously in the most efficient manner. This can easily be understood, when we consider the following:

In order to absorb as much heat as possible from the waste gases and transmit as much heat as possible to the incoming gas and air, the checker bricks should be laid in such a way that they present as much surface to the gases as possible. This can be done either by laying the bricks close together or by laying them staggered, that means, by laying them so that the small channels, which are formed by the bricks, run in a broken line instead of in a straight line. But such an arrangement, although of benefit to the heat transmission, would prevent a free and undisturbed passage of the gases, because it would form obstructions or restrictions in the passageways.

On the other hand, if the checker bricks are laid with the intention of providing free and easy passages for the incoming and outgoing gases, they would have to be laid far apart and would not be fit to perform their other duty, that is, absorbing and transmitting the heat. We see that in laying out the checker chambers we have to follow the happy medium, in order to get the best results obtainable.

There is another claim made in regard to the disadvantage of using checker chambers. This claim is based on the dissociation of the gas when exposed to high temperatures. It holds true for natural gas, but it does not hold true for producer gas under the conditions prevailing in glass factories. At high temperatures the heavy hydrocarbons, contained in natural gas as well as in producer gas, will be decomposed. For natural gas, containing from 95 to 98 per cent of these constituents, this decomposition would be detrimental; and for this reason natural gas-fired furnaces have regenerating chambers for air only. For producer gas, however, the decomposition would not be of very much influence, as this fuel, in most cases, contains only 3 or 4 per cent of heavy hydrocarbons. The loss in heating value would be small and the small amount of soot, deposited in the checkers and coming from the decomposition, would easily burn out and would not clog the channels, as would be done by the large amount of soot remaining from the decomposition of natural gas, if it ever were tried to preheat this fuel. A high temperature in the checkers is, therefore, harmless for producer gas, as can be seen in any open-hearth furnace; but in glass furnaces, the temperature in the checker chambers is seldom so high that the hydrocarbons will be decomposed. In most all cases, this temperature remains below 1500° F; and it is at this temperature that decomposition starts. There is, for this reason, no cause for distrust against using regenerative furnaces on the part of the glass factory managers.

Gas and air before entering the furnace and the waste gases after leaving the furnace have to pass through a set of reversing valves, the size of which must be determined to suit the conditions. Too small or too large openings are detrimental to the correct working of the furnace, as they influence the flow of the

gases. A glass furnace has these reversing valves in common with an open-hearth furnace in a steel plant; but as the ruling temperature in our case is only about 2650° F, there is no need for a large number of regulating dampers, which are necessary for an open-hearth furnace, having a ruling temperature of about 3100° F. A stack damper must, of course, be provided.

It may be well to point in this connection to an idea which is entertained by many a glass house superintendent. If they are reminded of the extended application of producer gas in the steel industry, they invariably will answer: "But a steel furnace is something entirely different from a glass furnace." There is no reason for such an answer at all. A regenerative furnace is a regenerative furnace, no matter for what it is used, the only difference between the two types being the temperature required in the hearth. If it is possible to obtain 3100° with producer gas in an open-hearth furnace, it must be possible to obtain 2650° with the same fuel in a glass furnace, as long as the furnace is built right. And right here is the point which is neglected in many cases. It is true, some furnaces do not work the way they should work, but the blame is laid on the fuel and not on the furnace. If the gas is made right, if the furnace is designed and built right and if it is watched carefully, it must give good results, provided the stack is of the right size.

Size of Stacks

This stack proposition is another item which is often neglected. The dimensions of many of these stacks are designed according to Kent's well-known tables of boiler stacks. A boiler stack, however, cannot be compared with a furnace stack, and this table should, therefore, not be used at all. An example will prove this statement. Supposing we have a furnace using an equivalent of 250,000 cu. ft. of natural gas per 24 hours. The stack dimensions from Kent's table are: height 90 feet, mean diameter 39 inches, while they should be: height 112 feet, mean diameter 66 inches. This difference is too large to be neglected. Every furnace should be provided with its own stack, as the regulation of the draft is then made easier and more effective.

Use of Producer Gas in Lehrs

The only place where there would be any reason for refusing to use producer gas would be in the lehrs and glory-holes and in similar furnaces. Due to the way these appliances are built producer gas cannot be burned in them without sulphuring the ware, thus either increasing the cost of production, as the thin white coating has to be washed off, or making the ware valueless, when this coating is too thick to be washed off. To overcome this trouble in lehrs, muffles have been designed, which are intended to keep the ware protected from the flame. But, are these muffles necessary? I have seen open lehrs fired with coke, which contains sulphur, yet the ware was clear; I have seen open lehrs fired with natural gas in which the ware was highly sulphured; and I have seen open lehrs fired with producer gas which did not sulphur. Why should producer gas sulphur the ware, if coke does not do it? It all depends on the correct design; if this is right, there will be no trouble from sulphuring when using producer gas.

Conclusion

Concluding, I want to say, that there is at the present time no necessity for the glass factory managers to be afraid of using producer gas as fuel. If the right type of producers is installed, if the whole plant is laid out right, and if the furnaces and the other appliances are designed and built right, producer gas will not only be as good a fuel as natural gas, but it will be a better fuel, besides being cheaper than natural gas in all cases, and cheaper than fuel oil in many cases.

Appendix

COMPARATIVE CALCULATION OF FIRST COST AND OPERATING COST FOR FUEL OIL AND PRODUCER GAS

The following calculations are based on a daily consumption of 1,500,000 cu. ft. of natural gas and of 500,000 cu. ft. of natural gas. For simplicity's sake, we will assume 10 cu. ft. of natural gas to be equivalent to 1 pound of coal, and 140 cu. ft. of natural gas to 1 gallon of fuel oil.

A. Large Plant

| | |
|--|-------------------|
| Daily consumption of natural gas..... | 1,500,000 cu. ft. |
| Corresponding consumption of oil..... | 11,000 gallons |
| Corresponding consumption of coal..... | 75 tons |

1. First cost of fuel oil plant

| | |
|--|----------|
| 8-10,000 gallon storage tanks, at \$1700.00 each..... | \$13,600 |
| Foundation, erection and so forth..... | 1,000 |
| Circulating pumps and motor..... | 500 |
| Piping, valves, fittings and air connections..... | 10,000 |
| Connections to furnaces, burners and so forth..... | 6,300 |
| Pumps and other appliances, blowers, motors and blast connections..... | 5,000 |
| Total..... | 36,400 |
| Say..... | \$36,500 |

The gas producers gasify 75 tons of coal per 24 hours or 6250 pounds of coal per hour. Figuring on an installation of hand-poked producers with a capacity of 1100 pounds of coal per hour, we need 6 producers. Counting one extra for spare, makes 7 producers.

2. First cost of gas producer plant with hand-poked producers

| | |
|--|----------|
| 7-10 feet i. d. producers, at \$2,000 each..... | \$14,000 |
| Buildings, foundation, excavation, erection, freight and so forth..... | 14,000 |
| Coal crushing and conveying machinery..... | 6,000 |
| Coal bunkers..... | 6,500 |
| Steam and water piping along producers..... | 2,500 |
| Overhead flues, valves and so forth..... | 3,500 |
| Total..... | \$46,500 |

For mechanical producers, or gas producer machines, having a capacity of 3300 pounds of coal per hour, we have to install 2 producers. Figuring again on one for spare, makes 3 producers.

3. First cost of gas producer plant with mechanical producers

| | |
|---|----------|
| 3-10 feet i. d. producers, at \$12,000 each..... | \$36,000 |
| Building, foundation, excavating, erection, freight and so forth..... | 14,000 |
| Coal crushing and conveying machinery..... | 6,000 |
| Coal bunkers..... | 4,000 |
| Steam and water piping along producers..... | 2,500 |
| Overhead flues, valves and so forth..... | 3,000 |
| Total..... | \$65,500 |

The operating cost is figured for a day as unit and contains the fixed charges.

1. Operating cost for a fuel oil plant

| | |
|---|-------------------|
| Interest, depreciation, taxes and insurance at 16 per cent per year of \$36,500..... | \$ 16.00 |
| Fuel oil, at $11\frac{3}{4}$ cents per gallon, $0.1175 \times$ 11,000..... | 1292.50 |
| Labor, 16 men total, 2 shifts, 45 cents hour.... | 86.40 |
| One foreman..... | 7.00 |
| Electric current, air, and steam..... | 6.50 |
| Lubricating oil, waste and so forth..... | 1.00 |
| Total..... | \$1409.40 per day |

2. Operating cost for a gas producer plant, hand-poked producers

| | |
|---|-------------------|
| Interest, depreciation, taxes and insurance at 16 per cent per year of \$46,500..... | \$ 20.38 |
| Coal, 75 tons, at \$3.50..... | 262.50 |
| Labor, 11 men total, 2 shifts, 45 cents hour.... | 59.40 |
| One foreman..... | 7.00 |
| Steam and water..... | 6.00 |
| Total..... | \$ 355.28 per day |

3. Operating cost for a gas producer plant, mechanical producers

| | |
|---|-------------------|
| Interest, depreciation, taxes and insurance at 16 per cent per year of \$65,500..... | \$ 28.71 |
| Coal, 75 tons, at \$3.50..... | 262.50 |
| Labor, 6 men total, 2 shifts, 45 cents hour.... | 32.40 |
| One foreman..... | 7.00 |
| Steam and water..... | 6.00 |
| Oil and waste..... | 0.50 |
| Current for motors..... | 3.00 |
| Total..... | \$ 340.11 per day |

Cost for natural gas

1,500,000 cu. ft. at \$0.32/1000 cu. ft..... \$ 480.00 per day

The equivalent cost for natural gas is

in the case of oil..... cents 94.0 per 1000 cu. ft.

in the case of producer gas

from hand-poked producers..... cents 23.7 per 1000 cu. ft.

from mechanical producers..... cents 22.7 per 1000 cu. ft.

Figuring on a cost of oil of 4 cents per gallon, and on coal of \$5.00 per ton, the corresponding figures would be:

| | |
|--|-----------------------------|
| Operating cost | |
| for the oil plant..... | \$556.90 per day |
| for the producer plant | |
| with hand-poked producers..... | 457.78 per day |
| with mechanical producers..... | 442.61 per day |
| and the equivalent cost of natural gas | |
| in the case of oil..... | cents 37.1 per 1000 cu. ft. |
| in the case of producer gas..... | |
| from hand-poked producers..... | cents 30.1 per 1000 cu. ft. |
| from mechanical producers..... | cents 29.5 per 1000 cu. ft. |

B. Small Plant

| | |
|--|-----------------|
| Daily consumption of natural gas..... | 500,000 cu. ft. |
| Corresponding consumption of oil..... | 3,600 gallons |
| Corresponding consumption of coal..... | 25 tons |

1. First cost of fuel oil plant

| | |
|---|----------|
| 3-10,000 gallons storage tanks, at \$1700 each..... | \$ 5,100 |
| Foundation, erection and so forth..... | 375 |
| Circulating pump and motor..... | 300 |
| Piping, valves, fittings and air connections..... | 5,000 |
| Connections to furnaces and so forth..... | 2,100 |
| Other appliances..... | 3,000 |
| Total..... | 15,875 |
| Say..... | 16,000 |

2. First cost of gas producer plant with hand-poked producers

| | |
|---|----------|
| 3-10 feet I. D. producers, at \$2000 each..... | \$ 6,000 |
| Building, foundation, excavation, erection, freight and so forth..... | 6,000 |
| Coal bunker..... | 500 |
| Steam and water piping along producers..... | 2,500 |
| Overhead flues, valves and so forth..... | 3,000 |
| Total..... | \$18,000 |

3. First cost of gas producer plant with mechanical producers

| | |
|--|----------|
| 1-10 feet I. D. producer..... | \$12,000 |
| Building, foundation, excavation, erection, freight..... | 5,000 |
| Coal crushing and conveying machinery..... | 5,000 |
| Steam and water piping along producer..... | 1,000 |
| Overhead flues, valves and so forth..... | 2,000 |
| Total..... | \$25,000 |

1. Operating cost for a fuel oil plant

| | |
|---|------------------------|
| Interest, depreciation, taxes and insurance at 16 per cent per year of \$16,000..... | \$ 7.00 |
| Fuel oil, 3,600 gallons at 11 ³ / ₄ cents gallon..... | 423.00 |
| Labor, 8 men total, 2 shifts, 45 cents hour..... | 43.20 |
| Electric current, air and steam..... | 5.00 |
| Lubricating oil, waste and so forth..... | 1.00 |
| Total..... | <hr/> \$479.20 per day |

2. Operating cost for gas producer plant with hand-poked producers

| | |
|---|------------------------|
| Interest, depreciation, taxes and insurance at 16 per cent per year of \$18,000..... | \$ 7.89 |
| Coal, 25 tons at \$3.50 ton..... | 87.50 |
| Labor, 6 men, 2 shifts, 45 cents hour..... | 32.40 |
| Steam and water..... | 3.00 |
| Total..... | <hr/> \$130.79 per day |

3. Operating cost for gas producer plant with mechanical producer

| | |
|--|------------------------|
| Interest, depreciation, taxes, insurance at 16 per cent per year of \$25,000..... | \$ 10.96 |
| Coal, 25 tons, at \$3.50 ton..... | 87.50 |
| Labor, 4 men, 2 shifts, 45 cents hour..... | 21.60 |
| Steam and water... .. | 3.00 |
| Current for motor, waste and so forth..... | 2.00 |
| Total..... | <hr/> \$125.06 per day |

Cost for natural gas

500,000 cu. ft. at \$0.32/1000 cu. ft.... \$160.00

The equivalent cost for natural gas is

| | |
|--------------------------------|-----------------------------|
| in the case of oil..... | cents 95.8 per 1000 cu. ft. |
| in the case of producer gas | |
| from hand-poked producers..... | cents 26.2 per 1000 cu. ft. |
| from mechanical producer..... | cents 25.0 per 1000 cu. ft. |

Figuring again on oil for 4 cents gallon and on coal for \$5.00 per ton, the corresponding figures are:

Operating cost

| | |
|--------------------------------|------------------|
| for the oil plant..... | \$200.20 per day |
| for the producer plant | |
| with hand-poked producers..... | 168.29 per day |
| with mechanical producer..... | 162.56 per day |

The equivalent cost of natural gas is

| | |
|--------------------------------|-----------------------------|
| in the case of oil..... | cents 40.0 per 1000 cu. ft. |
| in the case of producer gas | |
| from hand-poked producers..... | cents 33.7 per 1000 cu. ft. |
| from mechanical producer..... | cents 32.5 per 1000 cu. ft. |

Table Showing Cost for Oil and Producer Gas

Daily capacity of plant: 1,500,000 cu. ft. of natural gas

| | Kind of fuel | First cost \$ and % | Oil 11 ³ / ₄ cts. per gal. Coal \$3.50 per ton | | Oil 4 cts. per gal. Coal \$5.00 per ton | |
|----------------------|-------------------------|------------------------|---|--|--|--|
| | | | Oper- ating cost \$ per day and % | Equiv. cost of nat. gas Cts. per 1000 cu. ft. | Opera- ating cost \$ per day and % | Equiv. cost of nat. gas Cts. per 1000 cu. ft. |
| Producer gas from | Oil..... | 36,500 100% | 1409.40 100% | 94.0 | 556.90 100% | 37.1 |
| | Hand-poked producers... | 46,500 127.4% | 355.28 25.2% | 23.7 | 457.79 82.2% | 30.1 |
| | Mechanical producers... | 65,500 179.4% | 340.11 24.1% | 22.7 | 442.67 79.5% | 29.5 |

Daily capacity of plant: 500,000 cu. ft. of natural gas

| | | | | | | |
|----------------------|-------------------------|------------------|-----------------|------|-----------------|------|
| Producer gas from | Oil..... | 16,000 100% | 479.20 100% | 95.8 | 200.20 100% | 40.0 |
| | Hand-poked producers... | 18,000 112.5% | 130.79 27.3% | 26.2 | 168.29 84.1% | 33.7 |
| | Mechanical producers... | 25,000 156.3% | 125.06 26.1% | 25.0 | 162.56 81.3% | 32.5 |

NOTES ON TERRA COTTA SLIPS WITH REFERENCE TO THE USE OF ASBESTOS AND CHLORITE MICA

BY HEWITT WILSON

Introduction

History.—Since the beginning of terra cotta work in this country in 1853, there has been a constant demand and considerable search for new methods of decoration. And while there have been changes in the character of the molding and body ornament, the greatest changes have been made in the exterior protective coatings. To quote Doctor Ries “Most of the earlier terra cotta did not have its surface covered with a coating and protective slip * * * * although the practice became widespread about 1884. The dull texture vitrified slips were the first coatings used. Full glazes were not introduced commercially until 1897.” Mat glazes and polychrome decorations are of comparatively recent origin. At the early dates the surface was often decorated with markings and colors to match the building stones used in conjunction with the terra cotta.

Notwithstanding the fact that terra cotta is being made in highly colored decorations, the body underneath the coating is very similar to those of earlier dates. In fact because cone 8 was a common temperature for burning terra cotta, some of the older and, it is true, darker colored bodies have shown better weathering qualities than many of recent production.

Classification.—At the present time we can divide the terra cotta manufactured in this country into three general classes, high-, medium- and low-fired. High-fired ware is that fired to cones 6-7; medium-fired is that fired to cones 3-4; and low-fired ware is that burned below cone 3, usually in the neighborhood of cones 01-3. Classified according to the character of the exterior coating we have two general classes, vitrified coatings and glaze coatings. The original vitrified coatings were composed of natural slip clays and were usually buff, brown or red in color.

These natural clay slips, blended with more or less fluxing material, are still used to a considerable extent for producing the darker colored vitrified coatings. When light grays were wanted, it was necessary to use slips similar to porcelain or earthenware bodies slightly colored or spotted according to the color and grain of the stone to be matched. For the present day high-fired terra cotta, vitreous, ink-proof, white slips can be produced with mixtures of feldspar, ball clay, kaolin, flint and Cornish-stone as a base. But for the lower temperatures, especially below cone 4, the addition of fritted fluxes is a common practice.

For glaze coatings, the bristol glaze with its later addition of barium, magnesium and tin oxides, has served for firing above cone 4, while fritted glazes are used below that heat. Salt glazing has been used to a limited extent.

Vitrified Slip Coatings

From this general survey we wish to center our attention on those white or light gray vitrified slip coatings fired to about cone 6. They are called "standard finishes" or "vitrified slips." As to the preparation, they are either churned by paddles revolving in a stationary tank, blunged in a revolving barrel mill with but few pebbles, soaked and blunged by hand, or ground like a glaze in a regulation ball mill.

Defects of Vitrified Slips.—Comparatively speaking, there is very little trouble due to peeling, that is, a separation of the slip from the body. The clay content is usually high enough to provide proper adhesion to the body underneath. However, a great many vitrified slips which show good adhesion when used alone will show poor holding qualities when covered with a glaze, or, in other words, when the slip is used as an underslip.

Variations in color are usually caused by variations in the thickness of the coating, variations in the burning treatment, such as uneven temperature or flashing, and the use of a slip which verges too close to complete fusion, such as is obtained by an excess of fluxing material. In this case the usual variations in heat distribution will cause marked differences in shade and color. Coloring ingredients, such as iron and manganese, volatilize to a certain extent in the firing, and uneven burning condi-

tions will cause variations in color. Uniformity of color places terra cotta in a distinctive class of ceramic ware. The surfaces are large, the individual units are grouped together in the wall of a building, where, under changing lights and observation from all angles, any off-colored units will stand out distinctly. Moreover, the uniformity of color depends on a coating about two-hundredths of an inch thick to hide a buff-colored body.

Cracking is due to a number of causes. It may be due to the fault of the slip itself or to the body beneath. When due to the former, it is usually the result of faulty composition or too heavy spraying. Any slip will show drying or burning cracks when it is applied in too heavy a coating. It is a great temptation for the sprayer to add a little more slip and be sure there is enough on the surface. Cracking in the ornament or internal angles likewise may be due to flooding the angle with wet slip.

A Typical Composition.—In order to avoid undue confusion we have selected a single slip which has been in use in a terra cotta plant for a number of years as a standard finish or vitrified slip. It may be used for whites or light grays or as a base for colored slips. The composition is as follows:

COMPOSITION K

| | |
|-------------------------|-------------|
| Flint..... | 20 per cent |
| Cornish stone..... | 45 |
| English china clay..... | 25 |
| English ball clay..... | 10 |
| | — |
| | 100 |

This is very similar to the formula given in *Trans. Am. Ceram. Soc.*, 16, pp. 163 and 169 (1914), by Coats and Phillips, who worked under Professor Binns. In these articles there is about 12 per cent ball clay, half English and half German. Here it was used as an underslip, that is, covered with glazes.

This slip has slight absorption when burned to cone 6-7. Although showing very good adhesion when used alone, it gives poor holding qualities when covered with a glaze at this temperature. Not that it shows peeling, but it gives a very easy separation from the body when the glazed surface is tapped with a chisel.

However, it has been used for commercial work as an underslip. If cracks develop in drying this slip, there will be no healing or mending during the burning process. It is practically free from cracking on a smooth or tooled surface when properly sprayed on body A. Considerable trouble is experienced from small surface cracks when this slip and many others are sprayed on terra cotta body B.

The following screen analyses were made on a blunged sample of each of the above-mentioned bodies.

| | —Body A— | | —Body B— | |
|-------------------------------|----------|--------|----------|-------|
| Plus 20 mesh..... | 2.4 | 4.6 | 4.3 | 10.7 |
| 20-40 mesh..... | 8.2 | 16.3 | 12.7 | 31.8 |
| 40-100 mesh..... | 20.0 | 39.8 | 9.5 | 23.8 |
| 100-200 mesh..... | 9.6 | 19.1 | 6.0 | 15.0 |
| Residue..... | 10.1 | 20.2 | 7.5 | 18.7 |
| <hr/> | | | | |
| Total non-plastic..... | 50.3 | 100.00 | 40.0 | 100.0 |
| Approximate clay content..... | 49.7 | | 60.0 | |
| <hr/> | | | | |
| | 100.0 | | 100.0 | |

Body A is composed of a mixture of soft plastic and sandy clays with 20 per cent grog. Body B consists of about 40 per cent grog with a mixture of soft clays, all of which show negligible amounts of residue on a 200-mesh sieve. The former has a shrinkage of about $\frac{7}{8}$ inch and the latter about 1.0 inch to the foot.

The Relation between Grog in a Terra Cotta Body and the Slip Coating

General Relations.—It may be said that the coarser the grog the greater will be the size of cracks in the slip coating; and the greater the number of coarse grog particles the greater the number of cracks. With the above slip, bodies containing grog which will pass a 65-mesh sieve seldom show cracking on plane or tooled surfaces which have not been mistreated. Grog particles which will be retained on a 65-mesh sieve are liable to cause surface cracks, the danger increasing with the number and size of the larger grains.

Seven bodies containing grog screened to the following sizes were made: 16-20, 20-30, 30-35, 35-48, 48-65, 56-100, less

than 100. The trial pieces gave very bad cracking with sizes above 30-mesh, and a moderate number of fine cracks with grog sizes between 30-65 mesh. The cracking is practically eliminated by reducing the size of the grains below 65-mesh.

It is out of the question to screen terra cotta grog to pass a 65-mesh screen or even a 30 mesh, because of the cost plus the danger of warping, cracking or dunting in the body on cooling. For discussion on dunting see *Jour. Am. Ceram. Soc.*, **1**, pp. 193-200. The majority of terra cotta grogs in use show at least a few per cent caught on a 20-mesh screen.

Effect of Coarse Grog.—If a plastic clay is mixed with coarse grog gains alone, for example, those caught between a 16- and 20-mesh, and the latter be evenly distributed throughout the body, a representative portion will be contained in the surface layer. Grog grains of this mesh are about 0.04 of an inch in diameter. If the piece has been finished the plastic clay will cover all parts of the surface grains, save projecting edges, which cannot be seen but can be felt and heard when a steel finishing tool is drawn across the surface. As the plastic clay between the grains shrinks in drying and burning, it will form depressions between these large grains. The surface will be roughened, and even the dry piece will show many cracks across the particles whose projecting edges have acted like wedges and split the clay mass as soon as a certain degree of brittleness developed. When the slip coating is sprayed on this dry surface, the water causes a swelling of the upper layer. This expansion is followed by another shrinkage. The disturbance produces even greater disruption on the surface, so that the usual slip, trying to adjust itself to the irregular surface, is likewise cracked.

Now if a grog mixture of the usual mechanical analysis is substituted for the uniformly coarse grains, the shrinkage of the plastic mass between the large grains will be reduced, the surface will be smoother and the cracking of the slip coating will be less. But as long as there is a plastic shrinkage mass between the large grains there will be a tendency to crack.

Here is a wide field for study—the determination of the proper proportion of sizes which will give the least surface trouble together with the best strength and ability to withstand tempera-

ture changes. A method similar to that used by Kirkpatrick¹ for fire clay and grog mixtures could undoubtedly be followed. Of course, different clays will show different results in this respect with the same grog mixture, so it is an individual problem after the principle has been established. It is believed that those clays showing the greater dry and burned transverse strength will be less liable to this trouble.

Action of Water on the Dried Surface.—By wetting the surfaces of the bodies containing the various sizes of grog we found that after repeated treatments, the surfaces containing grog caught on a 65-mesh sieve were more disturbed by the water than the finer sizes. This swelling and consequent shrinkage caused by the action of the water in spraying may have the same result as freezing and thawing soil, which tends to push out the hard particles embedded in it, such as stones, posts and stakes.

Hardness of Grog *versus* Sizing.—If the grog particles above 65-mesh are liable to cause cracking, care should be taken to maintain a uniform proportion of these troublesome sizes in order to produce uniform results. Using the same grinding machinery and the same mesh screen, different grog mixtures of varying hardness will give different proportions of the various sizes of grain. The harder grog, *i. e.*, that which will not pulverize so easily and will produce less dust with the same crushing force, will contain more of the larger and troublesome sizes per unit. For example, if grog C were substituted for grog D, the

| | Grog C | Grog D |
|----------------------|--------|--------|
| Terra cotta..... | 10 | 60 |
| Fire brick..... | 10 | ... |
| Pottery saggers..... | 80 | 40 |
| | <hr/> | <hr/> |
| | 100 | 100 |
| Plus 20 mesh..... | 11.9 | 3.6 |
| 20-40 mesh..... | 36.0 | 33.4 |
| 40-100 mesh..... | 23.4 | 29.3 |
| 100-200 mesh..... | 10.3 | 15.0 |
| Minus 200 mesh..... | 18.4 | 18.7 |
| | <hr/> | <hr/> |
| | 100.0 | 100.0 |

¹ Kirkpatrick, F. A., "Effect of Size of Grog in Fireclay Bodies," Bur. Standards, *Tech. Paper* 109.

increased number of the larger grains undoubtedly would cause more surface cracks. The pottery saggers in this case were much harder than the terra cotta.

Effect of Kind of Grog on Surface Cracking.—So far we have not been able to distinguish between hard and soft burned terra cotta, pottery sagger, fire brick and white ware if they were clean and ground to approximately the same screening analysis. The strength and absorption of these different bodies will vary however. The clause "ground to the same screening analysis" does not mean simply ground to pass the same mesh sieve, as these materials vary in hardness. Round silica grains, however, do cause more cracking due to the shape and to the movements caused by the volume changes of quartz when heated.

Relation of Pressing and Finishing to Surface Cracking

Method of Pressing.—Proper methods of pressing and finishing are essential to smooth, unbroken slip surfaces. The presser tears or cuts a lump of clay from the pile. If it is for the face of the piece, it is rolled and patted on a plaster board until the surface is smooth and the grog particles are covered. This bat is then thrown into the mold, smooth side of the clay next to the mold. If one is not large enough, other bats are slapped in until the face and sides are covered. Where the smoothed side of the clay bat lies unbroken on the plaster, it needs little further attention. However, at the union of the two bats, particularly where the smooth surface had to be broken to cover the plaster, the surface will be rough and groggy and needs further treatment. Thorough beating of the clay as it lies in the mold, before the partitions are built in, will eliminate the rough and broken places and cause the grog to leave the surface. You can often trace the outline of a bat of clay across the face of an ashlar on a poorly pressed piece by following the line of the surface cracks, which are the result of torn clay not properly smoothed.

Absorption of Water by the Mold.—If the clay has given up enough water to the mold, so that the piece can be "turned out" without distortion and bear its own weight, the face, which has lain next to the mold will be in a stiffened condition considera-

bly beyond its best plastic condition. The average of two trials gave us the following results, using dry plaster and clay masses of an inch thickness, covered with a glass plate:

| Results with Body B | (a) | (b) | (c) |
|---|-----|------|------|
| Time of contact between plaster and clay in minutes..... | 10 | 20 | 30 |
| Per cent water absorbed by plaster in terms of total water content..... | 5.9 | 10.1 | 10.5 |
| Per cent water absorbed by plaster in terms of dry weight of clay..... | 2.5 | 4.3 | 4.4 |

And this water is not evenly distributed throughout the mass. The average of seven trials gave between 2.0 and 3.0 per cent (in terms of dry weight of clay) less water in a thin section about 0.05 of an inch thick which had been against the plaster than sections taken from the interior and the outer surface. Undoubtedly, the skin of clay immediately on the surface contains even less water and is approaching brittleness.

Drying.—As a clay mass dries from the best plastic state, it gradually loses its moldability and becomes more brittle, although its strength is increasing at the same time. In this latter state, as the plastic working properties decrease, the clay also loses the ability to adhere when broken faces are pressed together. This is probably a gradual change. The rate of loss of water and the minimum amount of water needed for plasticity or moldability are properties peculiar to each clay. The safe working range is undoubtedly less for bodies containing coarse non-plastics, such as terra cotta grog, than for bodies in which the non-plastic content is in the state of ground feldspar or flint.

Methods of Finishing.—After the mold is stripped off the piece of terra cotta, it is usually allowed to stand and dry or stiffen before finishing. This interval will vary from one to twenty-four hours or even more, depending on the practice which has been found best for the body. Of the two samples given above, 24 hours was a good interval for body A which lost its water very slowly, while body B should be finished as soon as possible, as it lost its water content very quickly and easily.

There are two general methods of finishing, also, combinations of the two: Finishing with "steel," such as a trowel or a special

tool for ornament, edges or tooled surfaces, and finishing with a water brush, which is equivalent to the sponging of pottery in the leather hard state. Preceding the water brushing, the edges, corners and lines of the piece are straightened and the surfaces cleaned of the larger irregularities.

Finishing with Steel.—Rubbing a smooth trowel over a piece of clay in its best plastic state is similar to pressing a column of clay through the die of a brick machine. It is a smoothing pressure, followed by a release. Exposed particles of grog are pressed down by actual contact with the tool while the plastic clay, with ability to flow, is squeezed up and around the grog grains until they are embedded, save for that point which is in contact with the tool. They are not completely buried; you can not see them easily, but you can feel and hear the grating or scratching as the tool passes over the surface.

If the clay mass has dried until brittleness and the consequent decrease in moldability have developed, the clay is torn as it is pressed up around grog grains or as the grains are moved slightly in a horizontal direction. Though pressed together, a great many of these torn surfaces are not firmly bonded again and the cracks are easily reopened by the stresses which accompany drying and burning. It is easier to smooth a surface approaching the leather-hard condition. It resists visible deformation and polishes easily. Naturally there is a tendency for a presser to delay finishing his ware until it reaches the state in which it can be done most easily and quickly.

Finishing with Water Brush.—A soft, flat brush is dipped in water and the excess water pressed out on the edge of the bucket. The surface is then rubbed thoroughly. This action knits the torn surfaces and fills the minute cracks, increases the water content of the surface so that there is less difference between the interior and the surface, and either picks up and removes or partially buries, in a firm plastic mass of clay, the exposed grog grains. Water brushing is more rapid than steel finishing, and it can be used for ashlar, plain or tooled finish and for ornamental work. A soft sponge may be preferable to a brush for delicate ornament. As in the case of steel finishing, if dryness has progressed beyond

a certain stage this method of soaking the surface is ineffective as a preventative of slip cracking. From an actual count of cracks on tooled surfaces of regular ware (body B), the ratio of cracks on steel-finished to those on water-brushed areas was greater than 4 : 1.

Our observations lead us to believe that, on the average, better surfaces are produced by a corp of trained finishers working by the day than by leaving the pressers finish their own ware, especially if they are on piece work. This places the responsibility of the production of good surfaces in the hands of a smaller group of specially trained men so that there will be less tendency to neglect this important factor.

The Relation of Spraying to Surface Cracking

Specific Gravity of Slip.—This is the weight of a given volume of slip divided by the weight of the same volume of water. A ground-glass stoppered bottle of about one pint capacity gives good service. With no alkali, a specific gravity of about 1.350 gives a good spraying viscosity. However, 0.5 per cent soda ash allows the water content to be reduced so that the specific gravity can be raised to 1.470 and still give a good spraying slip. With the decreased water content the results are quicker drying, less shrinkage, less water soaking into the surface of the body, and less tendency toward cracking. A piece can be coated in one operation so that it is not necessary to allow it to stand and dry. More care must be taken in spraying as it is easier to get the slip too heavy in this case, as there is more dry material per unit volume of slip.

Methods of Spraying.—To avoid the two common evils in spraying slips, *i. e.*, thin and thick spots, we would suggest the following procedure: After removing all loose surface material by blowing and brushing, blow the slip swiftly over the entire piece, filling all body imperfections, minute cracks and ornamental internal angles. Shut off slip, hold the nozzle close to the surface and blow it dry, removing all excess slip from the internal angles and cavities. This puts a coating of slip *all over* the surface and helps avoid the pink spots of bare body. To tone up the piece, the ashlar surfaces and the exposed portions of the ornament

may need an additional coating. This can be applied immediately with the gun held at a distance. Care should be taken to avoid wetting the internal angles at this time.

Dry spraying, *i. e.*, that in which a water finish does not form but where the water content is so slow that the slip is deposited on the surface as dust is not a good method for slips which do not fuse and smooth out in burning. The surface is still rough and porous after firing. This method has been successful for filling the internal angles of glazed ware.

Changes in the Composition of Vitrified Slip Coatings

While the above slip K gives good results on bodies containing fine grog there is always trouble with bodies containing large amounts of coarse grog or in bodies which are badly finished. This slip was changed so as to give greater elasticity or covering action so that the condition of the body has less influence on the slip. The slips described below were weighed, ground in a ball mill for two hours and screened through a 40-mesh sieve. Each member was sprayed on a piece of terra cotta which had a finished surface of at least 7.5 by 10.5 inches. Both plain and tooled ashlar were used. The samples were burned in commercial terra cotta kilns to cone 6-7.

Examination of Burned Samples.—The burned samples were examined with reference to the following points:

(1) Comparison of colors, surface texture, blisters, and so forth.

(2) **Absorption.**—Red ink was painted on a portion of each sample and allowed to stand for at least 10 minutes. All that could be removed was then washed off with soap and water.

(3) **Cracking.**—As many cracks are practically invisible without close inspection or the use of hand glass, each sample was washed with a slip of coal dirt and water. After a second bath in clean water, all the minute cracks are revealed. This practically duplicates the treatment to which most of the ware is subjected in the wall of the building. Many jobs are set in apparently first-class condition and later found to be full of small crows-feet and cracks.

(4) **Crazing.**—The red ink plus the dirty water reveals crazing and dunting cracks. How many of these larger cracks, *i. e.*, crazing and dunting, which appear after setting in the wall can not be found in the factory is yet a question to us. It is surprising what a little dirty water will reveal on an apparently sound ashlar.

Variations in Composition.—A complete substitution of Brandywine feldspar (soda) was made for Cornish stone in each of the following series: Each series consisted of eight changes from the original or nine members. The slips were sprayed over body B.

| | (a) | (b) | (c) | (d) | (e) | (f) | (g) |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Flint..... | 0 | 5 | 10 | 15 | 20 | 25 | 30 |
| Soda spar or Cornish stone.. | 45 | 45 | 45 | 45 | 45 | 45 | 45 |
| Georgia kaolin..... | 20 | 15 | 15 | 10 | 10 | 7.5 | 7.5 |
| English ball clay..... | 35 | 35 | 30 | 30 | 25 | 22.5 | 17.5 |
| | <hr/> | <hr/> | <hr/> | <hr/> | <hr/> | <hr/> | <hr/> |
| | 100 | 100 | 100 | 100 | 100 | 100.0 | 100.0 |

Substitution of Brandywine Feldspar for Cornish Stone.—In each case as the soda feldspar increases, the color becomes grayer, for vitrification is increased and the translucency permits the body beneath to show. Likewise the gloss increases with the increase of Brandywine feldspar. There were no blisters. Practically the first four or five members of each series showed slight ink absorption and the last half of each series was ink-proof. This means that 22.5 to 45.0 per cent Brandywine feldspar plus 22.5 to 0.0 per cent Cornish stone gives more vitreous slips than those higher in Cornish stone.

Although there was an increase in vitrification with greater contents of Brandywine feldspar, yet the cracking was not diminished. An average of the group was about 300 per square foot.

Substitution of Flint for Clay.—*Color.*—A and B series containing 35 per cent English ball clay have a grayer or more creamy color than the rest of the series of lower ball clay content. There was a distinct sheen or gloss to the members containing high Brandywine feldspar and 25 to 30 per cent flint.

Absorption.—There was very little difference found between the members of high clay or high flint contents. Undoubtedly

with a great many trials, the highest English ball clay members would be the least absorbent.

Cracking.—There was a distinct difference between the series in which the flint content was 20 per cent or less and those of 25 and 30 per cent flint. For example, in the series F the cracking was as follows:

| | F1 | F2 | F3 | F4 | F5 | F6 | F7 | F8 | F9 |
|---------------------------------------|-----|----|----|----|----|----|----|----|----|
| Number of cracks per square foot..... | 255 | 73 | 22 | 64 | 75 | 55 | 13 | 15 | 5 |

In series G the number of cracks was at a minimum. The combination of Brandywine feldspar and at least 25 per cent flint gave a decided reduction of surface cracking.

Crazing.—While high soda feldspar and high flint gave a reduction in minute drying and heating cracks, the slips crazed badly on cooling. This was especially bad in the smaller kilns. It is a case of substituting one trouble for another. This crazing would cause series F and G to be discarded at once as unsuitable for commercial slips.

Miscellaneous Series.—A number of series were made using our original slip K containing 20 per cent flint. This combination has proved its practical value under one set of commercial conditions.

Substitution of Maine Potash Feldspar for Cornish Stone.—This gives a less vitrified slip, which is softer and more absorbent. With this combination of materials the potash feldspar gave less fluxing action than the Cornish stone or the Brandywine feldspar.

Substitution of American Ball Clays for English Ball Clay.—Kentucky Construction and Improvement Company's A and AA and Mandle No. 1 S. G. P. and No. 1 W. W. C., replacing English ball clay, gave whiter slips which are less vitreous and more absorbent. The Mandle No. 3 was more nearly a duplication of the English ball as it contained a high content of carbonaceous material and burned to a creamy color, similar to that produced by the English clay.

English ball clay seems to have a greater ability to cover a grogged surface without cracking than do the American ball

lays tested. The latter were tested in the slips singly and in various combinations. The English clay somehow gives a much smoother working action and even can be used as a slip alone with careful spraying. It produces an ink-proof surface at cone 7. However, the color is not white, but a light cream, so its use is restricted. A slip containing 100 per cent ball clay is dangerous with slight variations of thickness of spraying.

Substitution of English Ball for English China Clay.—The original slip contained 25 per cent English china clay and 10 per cent English ball clay. There was increasing cream color with higher ball clay content, slight increase in the number of cracks, and increase in vitrification.

From this series we found that at least 20 per cent English ball clay could be used in the above formula K with no marked change in color or increase in cracking. On the other hand, the increased ball clay did not decrease the cracking. Various slips containing 60 per cent English ball clay have given good result, save for the cream color.

Addition of White Lead.—White lead was added up to 12 per cent addition. Six to 12 per cent gave more glossy and less absorbent surfaces which had a tendency to blister. This was especially true with the highest contents of lead and in the presence of reducing gases. There was no apparent change when the lead content was under 6 per cent. At these temperatures a considerable quantity of lead was volatilized. The cracking was not diminished on poor surfaces, save where the blisters had obscured the cracks.

Addition of Ground Glass and Frits.—The object of these additions was to cause early fusion and greater strength at the low temperatures before the higher temperature fluxes gave action. Ground glass increases the gloss. This is especially noticed in slips where the content of glass varies from 10 to 20 per cent. The tendency to blister is marked in this same range. The opacity is diminished. The number of cracks is but slightly diminished unless there is a movement due to the development of gas vesicles, which occurs most easily with overburning or reduction.

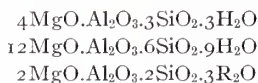
Similar results were obtained with a frit of the composition:



The blistering action is used at the present time to dull the surfaces of what would ordinarily be mat or semi-gloss glazes. The fused mass is full of minute blisters so that the reflection is broken up and the result, at a short distance, resembles the vitrified slip containing no frit. This method is principally used at lower temperatures for light cream or gray colors. Another method of dulling the surface is to introduce fine sand grains in an unground condition to the slip just before spraying.

The Introduction of Calcined Tennessee Ball Clay.—The object was to decrease the shrinkage of the slip and retard the development of cracks due to shrinkage. Clay was introduced in amounts up to 25 per cent. The ball clay was calcined to cone 6-7, ground wet in a ball mill to pass a 200-mesh sieve, dried and added to the mixture. The results were increased absorption, decreased shrinkage, increased number of cracks by weakening the slip, lighter colors, not over 10 per cent calcined Tennessee ball clay could be used.

Chlorite Mica.—Dana¹ classifies the chlorites as a group in the mica division. Normal formulas according to F. W. Clarke² are



"The minerals in this group are all silicates of alumina and magnesia (or iron) and contain about 12 per cent combined water. They are sometimes known as the 'hydro-micas.' In crystalline form they are very similar to the micas. However, they differ in being pliable, not elastic, softer and do not contain any large proportions of alkalis. The alumina content distinguishes them from talc and steatite."³

The analysis of "Canton A" chlorite, furnished by the American Mica Company, is as follows:

¹ "System of Mineralogy."

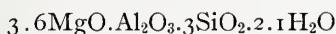
² "Data of Geo-Chemistry," U. S. Geol. Survey, *Bull.* 330, p. 331.

³ Miers, Henry A., "Mineralogy," MacMillan & Co.

| | |
|--------------------------------------|-------|
| SiO ₂ | 37.40 |
| Fe ₂ O ₃ | 3.92 |
| Al ₂ O ₃ | 21.30 |
| CaO..... | 1.77 |
| MgO..... | 27.36 |
| Ignition..... | 8.20 |
| | <hr/> |
| | 99.95 |

| | | |
|-----------|--------------------------------------|------------------------|
| 0.956 MgO | 0.292 Al ₂ O ₃ | 0.871 SiO ₂ |
| .044 CaO | .034 Fe ₂ O ₃ | .636 H ₂ O |

A general formula combining the lime, iron and magnesia, gives



which is very similar to Clarke's first normal formula. Different samples have been found to vary considerably. The chief trouble is the iron content which easily becomes too high for use in light gray or white slips.

Ten to 15 per cent of the chlorite mica added to K slip decreased the absorption so that the slips were practically ink-proof, decreased the cracking to a minimum without blistering, and darkened the color. With some samples of chlorite, the color was a light brown; with better grades, a light gray which could be used for most work. Above 15 per cent chlorite, the slip becomes more absorbent and darker in color. The decrease in the number of cracks may be due to the additional fluxing action of this silicate of magnesia and alumina or the interlocking plate-like action of the fine mica-like grains.

Asbestos.—Asbestos belongs to the serpentine and talc division of minerals. Most of the asbestos comes from the Canadian province of Quebec. The range of eleven analyses of asbestos (chrysotile) from the principal deposits of Canada gave.¹

| | |
|--|----------------|
| SiO ₂ | 39.05 to 42.64 |
| MgO..... | 40.07 42.97 |
| FeO and Fe ₂ O ₃ | 0.69 3.66 |
| Al ₂ O ₃ | ... 3.64 |
| H ₂ O..... | 13.47 14.50 |

The chlorite mica gave such an improvement in the elasticity of the slip that we thought we would still improve the fluxing

¹ Cirkel, Fritz, "Chrysotile-Asbestos," *Bull.* 69, 1910, Can. Dept. Mines.

action by eliminating the alumina content (common to the chlorites) and increase the physical action from that of a plate to that of a fiber.

After the asbestos rock has been mined and crushed it is sorted into various grades depending principally on the length of the fiber. The longest fibers are used in the manufacture of cloth and the shorter fiber and "sand" for cruder ware such as asbestos board, insulation coverings, fire-proof cements and electrical apparatus. The long fibers demand the higher price but contain the lowest content of iron. Likewise the long white fibers are very bulky and when ground with a slip or glaze require far more water than the more impure and heavier grades.

For our experiment we used two grades—John-Manville 60, at twenty cents per pound in pound lots, and their 201 A at three dollars per pound in pound lots. The 60 is a darker fiber of shorter length than the 201 A and contains more iron. The latter is very similar to that used in the backing of gas grates.

Grinding for three hours in a ball mill reduces the fibers, not to impalpable matter, but to smaller threads, which are still long enough to exert a fibrous action and yet are mobile enough to be sucked out of a pint cup and sprayed onto a piece of terra cotta.

More water must be used for the bulky 201 A fiber to give it low enough viscosity for spraying. Where the ordinary slip can be sprayed with a specific gravity of 1.470, a 4.0 per cent 201 A asbestos slip must be brought down to a specific gravity of 1.260. Consequently, because of the greater amount of water, an apparently thicker coating must be sprayed on the ware. One and 2 per cent 201 A slips and the 60 slips are more nearly normal.

Slips containing asbestos fiber can be screened only with great difficulty. The fibers easily clog and mat on the sieve wires. A 10- or 12-mesh screen will be about the finest mesh possible for large quantities of slip. Freshly ground slip would cause but little trouble with the ordinary spray guns. After slip has been standing in tanks for some time there may be considerable number of dry particles to screen out.

Asbestos slip does not flow evenly like the ordinary slip, but hangs together in wet clusters. This same effect is noticed in

spraying. There is too much of a spotting action, resulting in an uneven surface. As this shrinks in drying and burning, it smoothes out to a considerable extent and the fibers are fused into the mass of slip.

Such a slip can be painted or piled onto a dry clay surface with a spatula and form a smoother surface than by spraying. Likewise it will stand far more abuse in regard to thick coatings than the ordinary slips which crack very easily.

While the shrinkage is greater, the ability to fill internal angles of ornament without cracking is greater. Asbestos threads are crystals and have smooth sides like threads of glass. Wool and cotton threads are rough and cohere more tenaciously. If the asbestos slip is left to itself in drying and burning and does not have a body to adhere to, it shrinks considerably. When spread out in a thin layer over a dry surface, the crystal threads can slide over each other and still hold the mass together. This cohesion is so strong that sometimes there is bridging of the internal angles in place of the usual cracking. For a body which ordinarily showed surface cracking 1.0 to 3.0 per cent 201 A asbestos gave excellent results. The impure 60 fiber gave improved results also with small amounts. In one case, by actual count, the number of minute cracks on tooled samples 7.5 by 10.5 inches was as follows:

| | | | | | | | | |
|------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Per cent, 60 asbestos..... | 0.0 | 0.5 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 |
| No. of cracks per sq. ft.... | 983 | 108 | 18 | 27 | 29 | 35 | 18 | 9 |

One hundred cracks of the sizes counted passes as a perfect surface.

One or two per cent asbestos carrying five per cent iron oxide adds only 0.05 to 0.10 per cent iron oxide to the slip so that the ware is given but a slight gray color.

The fluxing action of two or three per cent asbestos seemed as great as that of 10 to 15 per cent chlorite mica, and we found:

a. The effect per unit weight was greater than that of white lead or the frits used up to contents of 5.0 per cent.

b. There is a possible improvement in the color when the iron-free asbestos is used.

c. There is a possible decrease in crazing with the high flint slips.

Asbestos in Glaze Work.—Asbestos has been tried on large-sized samples in the underslip for glaze work, with a view of filling the internal angles without cracking. The indications were good. Blistering was encountered when the content of asbestos in the underslip reached 3.0 per cent. One per cent added to the underslip gave a noticeable improvement.

Three per cent asbestos 201 A was included in the following mat glaze:

| | |
|-----------------------|-------|
| Maine feldspar..... | 16.4 |
| Cornish stone..... | 16.4 |
| Brandywine spar..... | 16.4 |
| Flint..... | 4.2 |
| China clay..... | 10.0 |
| Ball clay..... | 3.7 |
| Whiting..... | 9.1 |
| Zinc oxide..... | 8.5 |
| Barium carbonate..... | 7.0 |
| Tin oxide..... | 5.3 |
| Asbestos 201A..... | 3.0 |
| | <hr/> |
| | 100.0 |

Although it showed a very rough surface when dry, it fused and smoothed out normally at cone 6 and filled the internal angles nicely without an underslip when sprayed on the bare body.

It must be remembered that while the mica and asbestos slips have given good results on full-sized pieces of terra cotta, the study has not progressed beyond the experimental stage. The physical difficulties encountered with asbestos slips are great and would be troublesome with the ordinary commercial practice. The present prices of the better grades are prohibitive and would prohibit use, save on a small scale, such as for painting for polychrome work, and so forth.

General Conclusions

The physical condition of the body upon which vitrified slips and glazes are sprayed is of fundamental importance in the production of perfect surfaces. The maximum size of grog grains and the proportioning of the grog sizes, the methods of pressing, finishing and spraying are all of utmost importance.

While the composition of the slip needs thorough investigation, we would suggest that the shape of the individual particles be also investigated for the production of unbroken coatings. This includes the study of the magnesia and magnesia-alumina silicates as represented by asbestos, steatite and the minerals of the general mica division.

THE USE OF AMERICAN RAW MATERIALS IN THE MANUFACTURE OF WHITE WARE POTTERY¹

By A. V. BLEININGER AND W. W. McDANEL

At one time during the war the curtailment of shipments of kaolin and ball clay from England was seriously considered by the War Industries Board. This at once brought up the question as to whether satisfactory white ware pottery could be manufactured from domestic clays, it being understood, of course, that American feldspar and flint are already being used. Upon discussing this matter with Mr. Marcus Aaron, president of the United States Potters' Association, in April, 1918, it was suggested that a test be conducted consisting in preparing a series of bodies and making them into pottery under commercial condi-

TABLE 1—COMPOSITION OF BODIES

| No. | Feldspar | Flint | N. C. kaolin % | Del. kaolin % | No. 1 Ga. kaolin % | Washed S. C. kaolin % | Fla. kaolin % | Un-washed S. C. kaolin % | Tennessee ball clay % | Kentucky ball clay % |
|-----|----------|-------|----------------|---------------|--------------------|-----------------------|---------------|--------------------------|-----------------------|----------------------|
| 1 | 13 | 32 | 22.8 | .. | .. | .. | 15.2 | .. | 9 | 8 |
| 2 | 13 | 32 | 15.2 | .. | .. | .. | 22.8 | .. | 9 | 8 |
| 3 | 13 | 32 | 22.8 | .. | 7.6 | .. | 7.6 | .. | 9 | 8 |
| 4 | 13 | 32 | 15.2 | .. | 7.6 | .. | 15.2 | .. | 9 | 8 |
| 5 | 13 | 32 | 7.6 | .. | 7.6 | .. | 22.8 | .. | 9 | 8 |
| 6 | 13 | 32 | 22.8 | .. | 15.2 | .. | .. | .. | 9 | 8 |
| 7 | 13 | 32 | 15.2 | .. | 15.2 | .. | 7.6 | .. | 9 | 8 |
| 8 | 13 | 32 | 7.6 | .. | 15.2 | .. | 15.2 | .. | 9 | 8 |
| 9 | 13 | 32 | .. | .. | 15.2 | .. | 22.8 | .. | 9 | 8 |
| 10 | 13 | 32 | 15.2 | .. | 22.8 | .. | .. | .. | 9 | 8 |
| 11 | 13 | 32 | 7.6 | .. | 22.8 | .. | 7.6 | .. | 9 | 8 |
| 12 | 13 | 32 | .. | .. | 22.8 | .. | 15.2 | .. | 9 | 8 |
| 13 | 13 | 32 | .. | 22.8 | .. | .. | 15.2 | .. | 9 | 8 |
| 14 | 13 | 32 | .. | 15.2 | .. | .. | 22.8 | .. | 9 | 8 |
| 15 | 13 | 32 | .. | 22.8 | .. | 7.6 | 7.6 | .. | 9 | 8 |
| 16 | 13 | 32 | .. | 15.2 | .. | 7.6 | 15.2 | .. | 9 | 8 |
| 17 | 13 | 32 | .. | 7.6 | .. | 7.6 | 22.8 | .. | 9 | 8 |
| 18 | 13 | 32 | .. | .. | .. | 7.6 | 30.4 | .. | 9 | 8 |
| 19 | 13 | 32 | .. | 22.8 | .. | 15.2 | .. | .. | 9 | 8 |

¹ By permission of the Director, Bureau of Standards.

TABLE 1—(Continued)

| | | | | | | | | | | |
|----|----|----|------|------|------|------|------|------|-----|-----|
| 20 | 13 | 32 | .. | 15.2 | .. | 15.2 | 7.6 | .. | 9 | 8 |
| 21 | 13 | 32 | .. | 7.6 | .. | 15.2 | 15.2 | .. | 9 | 8 |
| 22 | 13 | 32 | .. | .. | .. | 15.2 | 22.8 | .. | 9 | 8 |
| 23 | 13 | 32 | .. | 15.2 | .. | 22.8 | .. | .. | 9 | 8 |
| 24 | 13 | 32 | .. | 7.6 | .. | 22.8 | 7.6 | .. | 9 | 8 |
| 25 | 13 | 32 | .. | .. | .. | 22.8 | 15.2 | .. | 9 | 8 |
| 26 | 13 | 32 | 19.0 | 19.0 | .. | .. | .. | .. | 9 | 8 |
| 27 | 13 | 32 | 15.2 | 15.2 | 3.8 | .. | 3.8 | .. | 9 | 8 |
| 28 | 13 | 32 | 11.4 | 11.4 | 7.6 | .. | 7.6 | .. | 9 | 8 |
| 29 | 13 | 32 | 7.6 | 7.6 | 11.4 | .. | 11.4 | .. | 9 | 8 |
| 30 | 13 | 32 | 3.8 | 3.8 | 15.2 | .. | 15.2 | .. | 9 | 8 |
| 31 | 13 | 32 | .. | .. | 19.0 | .. | 19.0 | .. | 9 | 8 |
| 32 | 13 | 32 | 15.2 | 15.2 | .. | .. | .. | 20.0 | 9 | 8 |
| 33 | 13 | 32 | 11.4 | 11.4 | 3.8 | .. | 3.8 | 7.6 | 9 | 8 |
| 34 | 13 | 32 | 7.6 | 7.6 | 7.6 | .. | 7.6 | 7.6 | 9 | 8 |
| 35 | 13 | 32 | 3.8 | 3.8 | 11.4 | .. | 11.4 | 7.6 | 9 | 8 |
| 36 | 13 | 32 | .. | .. | 15.2 | .. | 15.2 | 7.6 | 9 | 8 |
| 37 | 13 | 32 | 11.4 | 11.4 | .. | .. | .. | 15.2 | 9 | 8 |
| 38 | 13 | 32 | 7.6 | 7.6 | 3.8 | .. | 3.8 | 15.2 | 9 | 8 |
| 39 | 13 | 32 | 3.8 | 3.8 | 7.6 | .. | 7.6 | 15.2 | 9 | 8 |
| 40 | 13 | 32 | .. | .. | 11.4 | .. | 11.4 | 15.2 | 9 | 8 |
| 41 | 13 | 32 | 7.6 | 7.6 | .. | .. | .. | 22.8 | 9 | 8 |
| 42 | 13 | 32 | 3.8 | 3.8 | 3.8 | .. | 3.8 | 22.8 | 9 | 8 |
| 43 | 13 | 32 | .. | .. | 7.6 | .. | 7.6 | 22.8 | 9 | 8 |
| 44 | 14 | 32 | 14.0 | 17.0 | .. | .. | 8.0 | .. | 7.5 | 7.5 |
| 45 | 14 | 32 | 16.0 | 16.0 | .. | .. | 10.0 | .. | 6.0 | 6.0 |
| 46 | 14 | 32 | 12.0 | 12.0 | 8.0 | .. | 10.0 | .. | 6.0 | 6.0 |

tions at a number of East Liverpool plants. Accordingly, a co-operative arrangement was perfected between the United States Potters' Association and the Bureau of Standards according to which the latter was to prepare a series of bodies and to supervise the making up of the same at East Liverpool. The Association was represented by a committee consisting of Messrs. Joshua Poole, *Chairman*, H. N. Parker, Patrick McNicol, C. L. Sebring and W. L. Smith, Jr.

Experimental

General Procedure.—The committee was fortunate in securing for this purpose the experimental plant of the Patterson Foundry and Machine Co., at East Liverpool, which was prepared by thoroughly cleaning the blunger, piping and filter press and putting the machinery in the best condition. The

junior writer was in charge of the preparation of the bodies, personally attending to the weighing and the other manipulations, in which he was assisted by a slip maker of the Homer-Laughlin China Co., very expert in his line of work.

Each batch of 150 pounds, after having been filter pressed, was carefully numbered, kept moist and taken to one of the potteries where it was made up into ware, dried and bisque-fired. Ten potteries coöperated in this work.

Each body was accompanied by a question sheet filled out at the pottery, requiring detailed information concerning the working quality of the body, its behavior in drying, drying shrinkage, firing shrinkage, color, defects, and so forth. From each composition two dozen 8-inch plates and two dozen cups and saucers were made. Each piece was stamped with the body number. The pieces were finished and dried as usual and placed in saggers as is customary for bisque firing to cone 8. Standard cones were placed in the saggers. The plates were placed in the third ring, midway; the cups in the first ring, midway, and the saucers in the first ring and in the first four saggers from the bottom.

All of the bisque-fired pieces from the different plants were then taken to one of the potteries selected for this purpose, glazed with a regular whiteware glaze and glost-fired in one kiln to cone 4. In this manner the conditions of glazing were kept uniform and comparable for all of the pieces.

The glazed ware was collected and taken in baskets to the office of the United States Potters' Association. Unfortunately, a number of the question sheets accompanying the sets were lost in transit so that the shop data concerning a number of the bodies are lacking. Four bodies, 39, 40, 41 and 42, were not delivered for inspection. Upon the completion of the work the sets were arranged according to the body numbers and inspected by the committee of the United States Potters' Association. The findings of this jury concerning the appearance and ring of the ware were accepted as conclusive and are given in table 3.

Samples of each body were forwarded to the Pittsburgh laboratory of the Bureau of Standards, where the content of water of plasticity, volume drying shrinkage, modulus of rupture, volume

fire shrinkage and porosity at cones 7, 8 and 9 were determined. Duplicate sets of butters were also jigged at the laboratory in order to estimate the working quality of the bodies.

Clays Used.—The bodies were intended to show only the qualities of the different American primary and secondary kaolins. For this reason in 43 of the bodies the flint and feldspar were kept constant at 13 and 32 per cent, respectively, and the ball clays introduced as 9 per cent of Tennessee and 8 per cent of Kentucky ball clay. The variable factor then, is that relating to the 38 per cent of kaolin. No cobalt stain was used in any of the bodies, since color comparison would have been very difficult if this factor had been introduced. The general color of the body series, therefore, has a light cream tint, though some of the compositions compare very well with the regular pottery bodies to which cobalt has been added. The kaolins used were those from Florida, North Carolina, Georgia, Delaware and South Carolina, representing stock shipments, with the exception of the last named material, of which a special shipment was secured, consisting both of washed and unwashed clay. The materials were secured by the committee of the United States Potters' Association.

The compositions of the bodies are given in table 1. Constant feldspar, flint and ball clay contents are maintained in all but three compositions, 44, 45 and 46, which were suggested at a conference of potters held several years ago. In these series it was intended to cover the possible ranges of composition without including combinations which offer obvious practical difficulties.

For the purpose of estimating the amount of residue left by the different materials these were tested by passing them in the slip state through a 130 lawn with the following results:

| Material | Per cent residue |
|------------------------------------|------------------|
| South Carolina kaolin, raw..... | 10.75 |
| South Carolina kaolin, washed..... | 1.50 |
| North Carolina kaolin..... | 2.00 |
| Georgia kaolin..... | 6.00 |
| Florida kaolin..... | 1.00 |
| Flint..... | 6.50 |
| Feldspar..... | 1.50 |

Owing to the comparatively small quantity of body, 150 pounds, it was not thought necessary to blunge the materials more than from three to six hours, varying with the composition. The amount of water required was gauged according to the consistency commonly employed. The experimental blunger rotated at a speed of 56 revolutions per minute. The pressure employed in filtering was adjusted to give cakes of the proper consistency.

The amount of knockings left on the 130 lawn was determined in each case with the following results. The residues are higher than those usually found in pottery practice, which may be attributed to the shorter time of blunging:

TABLE 2—AMOUNT OF RESIDUE FROM EACH BODY LEFT ON A 130 LAWN

| | | | | | | | | |
|------------------|------|------|------|------|------|------|------|------|
| Body number..... | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Residue, %..... | 5.5 | ... | .. | .. | .. | .. | .. | 8.23 |
| Body number..... | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| Residue, %..... | 9.62 | 11.2 | 7.4 | .. | 5.71 | 4.45 | 4.95 | 4.9 |
| Body number..... | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| Residue, %..... | 5.25 | 3.51 | 5.73 | 2.82 | 1.93 | 3.13 | 3.49 | 2.34 |
| Body number..... | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| Residue, %..... | 5.95 | 2.09 | 4.96 | 6.11 | 6.97 | 9.55 | 6.99 | 8.73 |
| Body number..... | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| Residue, %..... | 8.76 | 4.77 | 5.78 | 6.6 | 4.39 | 5.99 | 5.72 | 7.40 |
| Body number..... | 41 | 42 | 43 | 44 | 45 | 46 | | |
| Residue, %..... | 4.42 | 7.07 | 6.70 | 4.50 | 4.28 | 4.24 | | |

The results of the work gathered from the returned question sheets, the results obtained at the Bureau of Standards laboratory, and the observations as regards the finished ware submitted by the committee, acting as the jury, are collected in table 3. For purposes of comparison two regular white ware bodies, V and P, from East Liverpool plants have been added.

Discussion of Results

Water of Plasticity.—The water content required by these bodies made from American materials does not average higher than that used in the regular bodies. There are exceptions, however, when larger quantities of Florida, Georgia and South Carolina clays are introduced with smaller proportions of North Carolina and Delaware kaolins. Thus the highest water content

obtained, 35 per cent, is obtained with 22.8 per cent of South Carolina and 15.2 per cent of Florida kaolins. The average water content of the bodies made from American materials is 31.3 per cent.

Drying Shrinkage.—The shrinkage upon drying was determined accurately for all of the bodies and expressed in terms of the dry volume. This was done as it affords the only method of obtaining the shrinkage values with the desired accuracy necessary for comparison. It is a well-known fact that linear shrinkage measurements are subject to considerable variation. As is to be expected, the drying shrinkage varies much like the water content, though not strictly parallel with it in every case. The average shrinkage does not differ materially from that of the two commercial bodies. There are, however, decided variations in the linear drying shrinkage of the bodies as taken from mold measurements which do not agree with the total shrinkage values as is to be expected, since the contraction is never uniform in all directions. In addition errors in measurement are apt to occur. The linear shrinkage measurements vary from 1.61 to 5.27 in terms of the wet length.

Behavior in Jiggering.—Nearly all the bodies behaved well in being made up into ware according to the shop reports. In a check series of jiggering trials made at the Bureau of Standards' laboratory only bodies 5, 44 and 46 were somewhat unsatisfactory.

Strength of Bodies in the Dried State.—Although it is generally assumed that the English ball clays are responsible for the plasticity and also the strength of white ware in the dried state, it was found in these tests that the use of American ball clays did not result in a lower average strength. In several cases the strength is greater than that of the usual commercial body.

The tests were made by pressing the body into bars, 7 inches long and 1×1 inch in cross section. After drying these were placed upon supporting rolls, 6 inches apart and a load applied at the center. The weight required to break the bars is used to compute the so-called modulus of rupture which indicates the transverse strength. It will be noted that moduli as high as

TABLE 3—RESULTS OF EXPERIMENTAL WORK

| No. of body | Makers of ware | Water con- tent of plastic body, % of dry wt. | Volume shrinkage, % of dry volume | Linear drying shrinkage of ware, % of wet length | Modulus of rupture of dried body, lbs. per sq. in. | Volume fire shrinkage, terms of dry volume, % at | | |
|----------------|----------------|---|--|---|--|---|--------|--------|
| | | | | | | cone 7 | cone 8 | cone 9 |
| 1 | H.-L. C. Co. | 33.30 | 22.50 | 3.12 | ... | 18.05 | 19.75 | 22.10 |
| 2 | H.-L. C. Co. | 32.20 | 23.50 | 3.12 | ... | 17.80 | 19.20 | 22.15 |
| 3 | H.-L. C. Co. | 29.75 | 18.40 | 3.12 | ... | 16.8 | 20.75 | 24.95 |
| 4 | H.-L. C. Co. | 30.40 | 22.25 | 3.54 | ... | 16.5 | 18.75 | 24.25 |
| 5 | H.-L. C. Co. | 33.45 | 25.10 | 2.64 | ... | 18.1 | 19.4 | 24.20 |
| 6 | H.-L. C. Co. | 29.40 | 19.30 | 1.17 | ... | 17.3 | 18.7 | 23.50 |
| 7 | H.-L. C. Co. | 30.40 | 19.90 | 1.77 | 311 | 17.05 | 19.15 | 19.75 |
| 8 | ..... | 31.15 | 21.30 | .. | 261 | 17.85 | 16.50 | 23.40 |
| 9 | ..... | 33.30 | 24.20 | .. | 296 | 18.15 | 20.25 | 22.20 |
| 10 | ..... | 27.70 | 15.30 | .. | 264 | 17.70 | 19.30 | 23.80 |
| 11 | ..... | 31.70 | 23.20 | .. | 319 | 17.25 | 19.25 | 22.50 |
| 12 | ..... | 30.50 | 21.60 | 4.44 | 319 | 18.70 | 19.60 | 22.25 |
| 13 | S. P. Co. | 32.00 | 22.50 | 2.49 | 322 | ... | 19.15 | 22.60 |
| 14 | S. P. Co. | 31.45 | 22.20 | 2.88 | 281 | ... | 18.05 | 22.20 |
| 15 | S. P. Co. | 31.30 | 20.03 | 2.49 | 277 | ... | 18.65 | 23.15 |
| 16 | S. P. Co. | 30.50 | 20.06 | 2.49 | 316 | ... | 18.10 | 21.35 |
| 17 | K. T. & K. Co. | 32.60 | 22.30 | 5.09 | 291 | ... | 18.50 | 21.65 |
| 18 | K. T. & K. Co. | 33.20 | 24.00 | 5.27 | 341 | ... | 20.1 | 21.70 |
| 19 | K. T. & K. Co. | 30.60 | 19.42 | 3.97 | 213 | ... | 19.25 | 23.25 |
| 20 | ..... | 30.40 | 21.06 | .. | ... | ... | 17.30 | 20.00 |
| 21 | ..... | 29.90 | 19.86 | .. | 275 | ... | 13.85 | 20.40 |
| 22 | ..... | 33.85 | 27.30 | .. | 296 | ... | 18.50 | 21.9 |
| 23 | ..... | 29.20 | 17.95 | .. | 236 | ... | 17.20 | 20.7 |
| 24 | ..... | 32.15 | 23.70 | .. | 281 | ... | 17.85 | 21.7 |

| | | | | | | | | |
|----|---------------------|-------|-------|------|-----|-------|-------|-------|
| 25 | ..... | 35.00 | 26.40 | ... | 308 | 18.35 | 19.75 | 23.0 |
| 26 | ..... | 31.95 | 21.50 | .. | 262 | 16.05 | 18.20 | 22.2 |
| 27 | C. C. T. P. Co..... | 31.40 | 22.1 | 2.19 | 249 | 15.30 | 17.55 | 21.8 |
| 28 | C. C. T. P. Co..... | 30.55 | 21.55 | 2.19 | 264 | 15.10 | 17.50 | 21.1 |
| 29 | C. C. T. P. Co..... | 31.85 | 23.05 | 3.24 | 296 | 15.95 | 17.20 | 20.4 |
| 30 | C. C. T. P. Co..... | 32.75 | 24.70 | 3.54 | 322 | 16.20 | 18.15 | 20.9 |
| 31 | ..... | 33.00 | 24.55 | .. | 346 | 17.55 | 18.70 | 26.6 |
| 32 | ..... | 30.25 | 18.65 | .. | 254 | 15.95 | 20.80 | 20.8 |
| 33 | ..... | 29.65 | 18.95 | .. | 304 | 15.85 | 17.65 | 21.1 |
| 34 | ..... | 31.50 | 21.95 | .. | 287 | 15.90 | 17.40 | 22.1 |
| 35 | E. M. K. C. Co..... | 31.60 | 22.60 | 5.05 | 291 | 15.95 | 18.05 | 20.80 |
| 36 | E. M. K. C. Co..... | 31.78 | 22.55 | 4.56 | 323 | 17.35 | 18.25 | 20.75 |
| 37 | E. M. K. C. Co..... | 29.50 | 18.40 | 3.76 | 266 | ... | 17.15 | 22.9 |
| 38 | E. M. K. C. Co..... | 31.45 | 18.4 | 3.87 | 321 | ... | 17.0 | 20.0 |
| 39 | ..... | 32.22 | 23.50 | .. | 241 | ... | 16.55 | 20.45 |
| 40 | ..... | 33.85 | 26.55 | .. | 303 | ... | 13.75 | 20.00 |
| 41 | ..... | 29.95 | 19.76 | .. | 200 | ... | 16.85 | 20.00 |
| 42 | ..... | 31.45 | 21.8 | .. | 224 | ... | 16.75 | 20.15 |
| 43 | D. E. M. P. Co..... | 32.20 | 25.6 | 3.68 | 232 | ... | 16.70 | 19.30 |
| 44 | D. E. M. P. Co..... | 31.00 | 21.88 | 3.30 | 259 | ... | 16.10 | 20.40 |
| 45 | D. E. M. P. Co..... | 29.80 | 19.30 | 3.11 | 224 | ... | 16.55 | 19.80 |
| 46 | D. E. M. P. Co..... | 30.15 | 20.90 | 1.61 | 225 | ... | 15.80 | 19.25 |
| V | ..... | 30.10 | 20.20 | .. | 203 | ... | 21.05 | 25.25 |
| P | ..... | 31.55 | 22.20 | .. | 278 | ... | 22.00 | 24.55 |

TABLE 3—RESULTS OF EXPERIMENTAL WORK (Continued)

| No. of body | Linear shrinkage, % of dry length | Be-shrinkage, havior in jiggling | Drying behavior | Defects in bisque fire | Porosity at cones, % | | | General appearance of ware |
|-------------|-----------------------------------|----------------------------------|-----------------|------------------------|----------------------|------|-------|--|
| | | | | | 7 | 8 | 9 | |
| 1 | 7.63 | Good | O. K. | None | 22.9 | 19.5 | 14.00 | Fine specks, color good, 2 pieces crazed |
| 2 | 7.62 | Good | O. K. | None | 21.5 | 18.8 | 16.1 | Fine specks, good body and color |
| 3 | 7.62 | Good | O. K. | None | 21.4 | 18.3 | 14.1 | Clean, good body and color |
| 4 | 8.80 | Good | O. K. | None | 19.4 | 16.1 | 11.1 | Fine specks but good body and color |
| 5 | 7.40 | Good | O. K. | None | 21.2 | 18.5 | 14.9 | Like 4 |
| 6 | 3.56 | Short | O. K. | None | 20.9 | 17.3 | 12.0 | Good body and color |
| 7 | 6.20 | Good | O. K. | None | 21.4 | 18.5 | 13.6 | Clean body and good color |
| 8 | ... | Good | ... | ..... | 20.9 | 18.0 | 14.4 | Clean body and good color; some crazing |
| 9 | ... | Good | ... | ..... | 20.9 | 19.6 | 15.7 | Good color; some crazing |
| 10 | ... | Good | ... | ..... | 21.1 | 17.7 | 13.9 | Fair color; sound body |
| 11 | ... | Good | ... | ..... | 21.6 | 18.9 | 15.4 | Creamish color, sound body |
| 12 | 8.79 | Good | O. K. | None | 20.9 | 18.1 | 15.3 | Good color, warps a little, good ring |
| 13 | 7.05 | Good | O. K. | None | 21.6 | 18.5 | 15.4 | Fine color; some crazing |
| 14 | 6.13 | Good | O. K. | None | 21.3 | 15.7 | 14.5 | Fair color; some crazing |
| 15 | 7.28 | Good | O. K. | None | 22.4 | 20.1 | 13.6 | Excellent color, some crazing |
| 16 | 8.27 | Very good | O. K. | None | 21.3 | 20.0 | 15.1 | Not a very strong body; some crazing |
| 17 | 9.63 | Good | Fair | None | 21.8 | 20.9 | 18.4 | Good body and color |
| 18 | 10.20 | Good | O. K. | None | 21.8 | 19.8 | 16.7 | Excellent color, body fair |
| 19 | 8.10 | ... | O. K. | 1 pc. cracked | 21.8 | 19.2 | 14.8 | Fair color, good body, some crazing |
| 20 | ... | ... | ... | ..... | 22.5 | 21.0 | 16.6 | Fair color; not a strong body; crazed |
| 21 | ... | ... | ... | ..... | 22.6 | 21.0 | 17.9 | Good color; body below average; crazed |
| 22 | ... | ... | ... | ..... | 20.8 | 18.3 | 14.7 | Color below average; crazed |
| 23 | ... | ... | ... | ..... | 22.5 | 20.7 | 17.1 | Color good; body weak; crazed |
| 24 | ... | ... | ... | ..... | 23.0 | 22.2 | 16.1 | Good color; crazed |

| | | | | | | | | |
|----|------|-------|-------------------------|------|------|------|-------|--|
| 25 | ... | .... | ... | .... | 22.2 | 20.4 | 16.5 | Good color; not crazed |
| 26 | ... | .... | ... | .... | 22.7 | 20.3 | 16.5 | Fair color; underfired; crazed |
| 27 | 6.6 | Fine | O. K. | None | 22.3 | 20.8 | 15.8 | Good color and texture; crazed |
| 28 | 7.24 | Fine | O. K. | None | 22.4 | 21.0 | 15.5 | Good color and body; crazed |
| 29 | 7.69 | Fine | O. K. | None | 23.3 | 20.7 | 17.3 | Fair color and fair body; crazed |
| 30 | 8.26 | Fine | O. K. | None | 22.8 | 20.7 | 16.8 | Good color and body; crazed |
| 31 | ... | Good | ... | .... | 22.4 | 21.3 | 16.8 | Good color but body too open; crazed |
| 32 | ... | Good | ... | .... | 24.1 | 23.0 | 18.5 | Good color; ring not good; crazed |
| 33 | ... | Good | ... | .... | 23.3 | 21.0 | 16.4 | Good color; ring fair; some crazing |
| 34 | ... | Good | ... | .... | 22.9 | 21.0 | 16.5 | Good color and ring; crazing |
| 35 | 9.19 | Good | O. K. | None | 21.7 | 20.9 | 16.7 | Good color, body very good; some crazing |
| 36 | 9.27 | Fair | O. K. | None | 18.7 | 20.0 | 17.0 | Excellent color; fine body |
| 37 | 7.8 | Fine | O. K. | None | 22.7 | 21.8 | 17.4 | Good color; excellent body; crazed |
| 38 | 8.27 | Fine | Sl. warp. 1 pc. cracked | ... | 23.2 | 22.2 | 18.1 | Good color and body; some crazing |
| 39 | ... | Good | ... | .... | 23.4 | 22.4 | 17.8 | |
| 40 | ... | Good | ... | .... | 23.3 | 21.4 | 18.2 | |
| 41 | ... | Good | ... | .... | 22.8 | 22.1 | 18.1 | |
| 42 | ... | Good | ... | .... | 22.9 | 22.2 | 18.6 | |
| 43 | 7.29 | Good | O. K. | None | 23.4 | 24.1 | 19.3 | Good body and color |
| 44 | 6.25 | Fair | O. K. | None | 23.1 | 22.1 | 16.15 | Good color and body; crazed |
| 45 | 5.95 | Good | O. K. | None | 23.3 | 22.1 | 17.0 | Good color but body not matured; crazed |
| 46 | 5.20 | Short | O. K. | None | 22.2 | 21.9 | 12.3 | Fair color and body; crazed |
| V | ... | Good | ... | .... | 18.1 | 15.8 | 10.3 | |
| P | ... | Good | ... | .... | 18.8 | 16.1 | 10.1 | |

341 pounds per square inch were obtained, the average of the series being 279 pounds against the values of 203 and 278 of the two East Liverpool bodies. It is apparent, therefore, that no loss in strength occurs due to the use of American clays.

It might be added that no drying defects occurred in the ware made or in the specimens made in the laboratory.

Fire Shrinkage.—The total burning shrinkages were determined in the laboratory and expressed in percentage contraction figured on the basis of the dried volume. Using a large test kiln of 1 cubic yard capacity, fired with natural gas, the bodies were fired to temperatures corresponding to cones 7, 8 and 9, the time taken for the burn being about the same as in the commercial bisque fire. The specimens were made in the form of briquettes, about $2 \times 1 \times 1$ inches. The volumes were determined in the dried state and after each firing.

Confining our attention to the temperatures of cones 8 and 9, it will be observed that the average shrinkages of the 46 American clay bodies are 17.8 and 21.7 per cent, respectively, as compared with 21.5 and 24.9 per cent, which are the values obtained for the two standard bodies employing English kaolin. It is evident, therefore, that the American kaolins and ball clays resist vitrification to this extent and would require a higher temperature of firing if the same fire contraction were to be required. At cone 9, however, it is evident that the fire shrinkage is progressing with very much greater rapidity. Thus body 31 shows an increase in volume shrinkage from 18.7 to 26.6 per cent between cones 8 and 9. Other bodies which show a volume fire shrinkage of 23 or more per cent at cone 9 are 3, 4, 5, 6, 8, 10, 15, 19 and 25.

Porosity.—The porosity of the fired bodies expressed by values showing the percentage of voids or pore space in terms of the exterior volume of the piece is a still better criterion of the stage of vitrification than the shrinkage. It will be noted that the bodies, employing English clays, show a mean porosity of 15.9 per cent at cone 8 and 10.2 per cent at cone 9. These figures are useful for purposes of comparison, but it must be remembered that they represent the joint effect of English kaolin

and ball clays. Studying the porosity figures for cone 8 it will be seen that but two bodies show a porosity of 16 per cent, namely 4 and 14. It would seem from this that the Florida and Georgia kaolins promote vitrification decidedly, which, of course, is a well-known fact. Assuming arbitrarily that a porosity of 19 per cent is permissible for whiteware fired to cone 8 we would have the following bodies pass this requirement: 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13 and 14. These are all bodies containing not more than 22.8 per cent of primary, or non-plastic, kaolins, such as the North Carolina and Delaware, together with Georgia or Florida kaolin, or both. It was found also that these bodies, with the exception of 8, 9, 13 and 14, showed no evidence of crazing in the finished ware. Beyond body 14 the introduction of South Carolina kaolin makes the bodies more refractory. Beginning with body 26, the bodies continue to be porous owing to the introduction of too large an amount of both North Carolina and Delaware kaolin, the introduction of South Carolina kaolin, or to both causes simultaneously.

Referring now to the temperature of cone 9, we find the general average of porosity of the American clay bodies to be 16 per cent, compared with 10.2 per cent for the typical East Liverpool compositions. Only three bodies approach the latter porosity value, namely, 4, 6 and 46. Assuming an arbitrary porosity limit of 15 per cent, it will be noted that the first ten compositions contain 8 bodies corresponding to this degree of density, indicating in a general way that the remarks made concerning the cone 8 firing apply. But at the same time it is apparent that the bodies as a whole are more refractory than those commonly made with English china clay and ball clay, and that we cannot expect to reach greater density without employing more feldspar. It is to be expected, however, that with 14 or 15 per cent of this constituent bodies sufficiently close may be obtained, especially if the firing can be carried somewhat higher than cone 8.

Defects in the Bisque.—Practically no defects were noted as regards cracking or checking in the bisque fire.

Appearance of the Ware.—It was the judgment of the committee that most of the bodies showed a very good color and appeared

to have a sound ring. No crazing was observed on the ware at the time of the examination by the committee with the exception of body 24. However, a set of pieces for each of the bodies was forwarded to the Pittsburgh laboratory where it was found, after six months, that bodies 9, 13, 22, 23, 24, 26, 27, 28, 29, 30, 32, 33, 44, 45 and 46 had crazed. All of the pieces were likewise subjected to a treatment consisting in placing them in boiling water and cooling them rapidly. This was repeated ten times and caused a number of additional bodies to craze.

This is what should be expected from bodies as porous as some of these are. It is evident that this can be remedied by an increase in the amount of feldspar or in the temperature of the bisque fire, or both. The drop in porosity necessary to produce ware free from crazing is not great since even under these conditions some of the bodies did not show this defect. The compositions which were found to show no crazing were 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 17, 18, 25 and 36. It is interesting to note that a porosity of 20 per cent seems to be about the limit at which the white-ware glazes may hold upon the body without crazing, though necessarily the boundary is not sharply defined. If the bodies, causing crazing, had been fired to a higher temperature, say cone 9, no crazing would have been observed.

Conclusions.—The question as to whether white ware pottery of satisfactory quality can be made from American raw materials exclusively must be answered in the affirmative on the basis of the facts presented. It is necessary to realize, of course, the fact that both the American ball clays and kaolins are of a more refractory nature than the English materials, especially the ball clays. This would necessitate the use of a slightly modified body composition consisting in using either more of the ball clay, or increasing the feldspar content by from 1 to 2 per cent, or in raising the firing temperature from $1\frac{1}{2}$ to 1 cone, or in a combination of any of these three changes. These modifications are by no means important and would entail no hardship to the manufacturer.

While the present work did not concern itself with the question of an adequate supply or the uniformity in quality of the domestic clays it will be necessary to discuss briefly the real situa-

tion. It is a well-known fact that the closest approach to English china clay is obtained with a mixture of primary kaolin, such as the North Carolina or Maryland kaolin, with a secondary one, of the type of the Georgia or Florida plastic kaolins. Such a combination presupposes, therefore, the existence of an adequate supply of the primary kaolins. It is in this respect that we are lacking. While some very fine kaolin is being obtained from the North Carolina districts the quantity being marketed is not adequate for the needs of the entire industry. A similar condition exists with reference to the Maryland and Delaware deposits. Even though the amount of primary kaolin used were cut down to the minimum, an adequate supply could not be obtained at the present time. As to the exclusive use of plastic kaolins this is much easier said than done, as all practical potters know, and cannot be considered a feasible proposition. This situation is complicated by the needs of the paper industry, the tonnage of which greatly exceeds that required in the manufacture of pottery. It is evident that competition for all suitable materials on the part of the paper industry is a factor to be reckoned with. The question of the cost of the domestic and imported kaolins, also, cannot be disregarded, though it is of secondary importance, compared with the fundamental question of actual clay resources.

We are hence compelled to arrive at the conclusion that while white ware pottery of good quality can be produced with the exclusive use of domestic kaolins, the output of our mines is not sufficient to justify the elimination of the English china clay, which is supplied in uniform quality and at a cost competing closely with that of the domestic product. On the other hand, every effort should be made to increase the production of our kaolin mines and to search for new deposits so that ultimately we may be entirely independent of other countries with references to such basic materials as primary kaolin.

Furthermore, it should be the aim of every potter to make use of domestic clays to the fullest possible extent so that the kaolin mining industry may find it profitable to enlarge and improve its operations. This policy is the only safe and wise one if we are not to be forever dependent upon foreign sources, which might

at some time fail us entirely through unforeseen conditions, such as legislative action prohibiting the export of the materials, etc.

The sincere thanks of the writers are due to the committee of the United States Potters' Association for its whole-hearted coöperation. The chairman, Mr. Joshua Poole, spared no pains to assist in this work. We are also greatly indebted to the pottery firms for carrying on the tests so carefully and the Patterson Foundry and Machine Company of East Liverpool for its generous assistance and coöperation.

BUREAU OF STANDARDS LABORATORY
PITTSBURGH, PA.

CRAFTSMANSHIP EXHIBITED IN FINE CUT GLASS

BY J. J. VALLELY

The purpose of this article is to sketch briefly the evolution of a piece of fine cut glass and to bring home to those persons whose taste happily makes them our readers, an appreciation of the specific qualities that give to one product the commanding place in cultured esteem. "The story of glass" excites the imagination at every step, from its primitive beginning to the point where craftsmen leave the well-worn path of mediæval method and press forward into the broader highway of modern science.

The artistic position of good quality, cut glass, places it noticeably apart from the poorer grades. To be capable of judging glass is to add vastly to one's pleasure in owning and in giving. There are few gifts more acceptable than nice cut glass. It appeals to people in all walks of life and while it is popular it would be even more popular if the majority of people knew what cut glass should be.

Cut glass being a hand product consists of: first, a pretty design (or pattern); second, workmanship in cutting the design; and, third, in finishing (or polishing). Skill, in cutting, means that the cuts should be true and sharp. All cuts crossing each other should be exactly the same in depth, and all the detail work carried out in the same exact manner. Finishing (or polishing) is the next important part, and all cuts should be polished to a sparkling brilliancy. The nicest piece of cutting can be easily spoiled by poor polishing. This is very often done in factories where they do not have the modern methods, or where quality is not considered, which, I regret to say, are quite common.

The methods of polishing glass have changed or advanced during the past twenty-five years. At one time it was not thought possible to produce a brilliant polish by the use of acids. A small factory near Boston, Massachusetts, proved that it was not only possible but very practicable. This factory demonstrated that

a very brilliant polish could be obtained and by this method the melted edges, produced by the fast revolving brush wheel, was done away with, and a better quality of cut glass produced. The acid finish at that time was called the "electric polish," and so cleverly did this company conceal the real method that it was years before it became known that acids were being used for polishing and not electricity. This process has done away with the greater part of wheel polishing.

About twenty years ago, the composition emery wheels for glass-cutting purposes were introduced. For several years they did not prove very successful, but later improvements have made them very popular as they are much superior to stone wheels for most lines of cutting.

As a piece of glass comes from the annealing oven, before it has received any decoration, it is known as a blank. In the early days of glass cutting all blanks were made plain. Today, to save work and cheapen production, figured blanks are often employed, that is to say, the design is pressed into the blank while the glass is in a plastic state. The result is that a great amount of poorly cut and finished cut glass is placed upon the market. It requires skill to cut a nice pattern on a plain blank but less skill is required to re-cut the pressed cuts on the figured blank. In fact, workmanship and quality on this line of pressed glass are forgotten and consequently a large amount of glass that is a discredit to the cutting industry finds its way onto the market.

When the glass is properly cut and polished on a plain blank, a refraction is produced, almost equal to that of a diamond. When the design has been pressed into the blank, the prismatic effect is practically neutralized, the color is clouded, the sparkle subdued. To detect the cut glass made from figured (or pressed) glass, simply run the fingers over the inside of the article where the cutting on the outside is deepest, and a slight swelling on the inside will be noticeable to the touch. However, this does not condemn all pressed cut ware if it is properly cut and polished.

A great many people, in buying cut glass, judge quality by the weight. I have seen people reject a first-class piece on account of its not being heavy, and select a very inferior piece that was of

greater weight. I am sure they would not follow this same practice in buying other lines of art ware. Of course, best quality cut glass is cut on lead glass, and lead glass is usually heavier than lime glass, but to select nice glassware one must look for a pretty design and good workmanship in the cutting and brilliancy rather than to try to judge by weight.

Another line of glassware that we find upon the market is known as semi-cut glass. This is sold in a great many stores and often is sold for real cut glass. This is a cheap line of pressed lime glass with a small amount of dull cutting inserted here and there. It makes a very poor substitute for nice glassware.

In conclusion, I will say that we find a very pretty line of light ware upon the market. This line includes engraved and cut floral designs, which are very pretty. This line, like all other lines of nice cut glassware, consists of pretty designs, good workmanship and finish.

THE SOLUBILITY OF BORIC ACID FRITS¹

BY GEORGE BLUMENTHAL, JR.

The extent to which boric acid frits for white ware glazes are soluble in water has been more or less a mooted question. Some have claimed that they are quite soluble while others have held to the contrary opinion. It was thought desirable, therefore, to determine the solubility of a number of commercial frits, representing both the sagger and the furnace methods of melting. Nine samples were obtained, which differed rather widely in appearance, some being glassy, others more of a stony character; some appeared to be quite homogeneous, others contained undissolved particles of flint or clay. The compositions of the frits were not known.

The specimens were ground, thoroughly mixed and sieved through 20- and 40-mesh sieves. The material used was that which had passed the 20 but was retained on the 40-mesh sieve. The surface exposed to the action of the water was, therefore, practically constant for each sample. The amount used in each case was five grams placed in a glass cylinder together with 350 cc. of distilled water. Blank runs were made with water alone. The glass cylinders were almost filled and placed on a shaking machine making about 17 revolutions per minute. The liquid and the samples were thus agitated gently for 24 hours. No allowance was made for variations in the room temperature, which could not be controlled, but which for a determination of this kind may be considered to be a negligible factor.

After three or four hours the water showed a more or less pronounced degree of turbidity, varying from a slight indication to a decidedly cloudy condition. This was evidently due to colloidal silicic acid which separated out.

After having been shaken for the required time the supernatant solution was carefully decanted off and filtered through hardened filter paper, which operation was repeated to insure practically com-

¹ By permission of the Director, Bureau of Standards.

TABLE SHOWING RESULTS OF SOLUBILITY DETERMINATIONS

| No. | Kind of frit | Appearance of frit | Colloidal silicic acid, % | Portion of frit soluble in water, % | Appearance of solution after shaking |
|-----|--------------|---|---------------------------|-------------------------------------|--------------------------------------|
| 1 | Frit kiln | Glassy and clean | 2.2 | 0.3 | Clear, little silicic acid |
| 2 | Sagger | Not thoroughly melted | 5.1 | 1.7 | Quite cloudy |
| 3 | Frit kiln | Glassy and well fused | 2.5 | 0.2 | Cloudy |
| 4 | Sagger | Poorly fused | 27.2 | 24.6 | Very cloudy; frit slaked |
| 5 | Sagger | Slightly opaque, clean | 2.2 | 1.9 | Quite clear |
| 6 | Sagger | Glassy, contains some undissolved flint | 4.6 | 1.8 | Cloudy |
| 7 | Sagger | Glassy and clean | 2.2 | 1.1 | Clear |
| 8 | Sagger | Well fused, hard, of smoky appearance | 2.2 | 8.0 | Clear |
| 9 | Frit kiln | Glassy, undissolved flint | 2.2 | 0.5 | Clear |

plete separation of the colloidal material. From the clear filtrate 50 cc. was removed, evaporated to dryness and the residue weighed.

The precipitate of colloidal silicic acid was likewise dried at 110°C and weighed as was the undissolved frit. From the latter figures the amount of dissolved material was checked. The results are compiled in the accompanying table.

It appears from these figures that all frits are somewhat soluble in water, a fact apparently due to the insufficient amount of melting they have undergone. This seems to be verified by the fact that those which have been melted in the furnace and have undergone more complete fusion show much lower solubility, though it is realized that the composition of such frits is also different. On the other hand, it is evident that sagger frits can be made so as to be insoluble for all practical purposes. In general, the more soluble the frit the more silicic acid is separated out, though there are distinct exceptions as in the case of 8.

From the operating standpoint only one frit should be expected to give trouble, No. 4, which evidently was insufficiently fused, a fact already indicated by its slaking. Considered theoretically, no objection can be raised against the type of composition employed which in spite of the high content of boric acid tends to produce insoluble borosilicates of which "Pyrex" glass represents an ideal example.

Although a discussion of the practice of fritting is not pertinent to the subject here under discussion it would seem that the use of the melting furnace would be desirable even from the standpoint of solubility since it would tend to produce frits uniformly insoluble, to say nothing of the saving in cost.

Again, in reference, to the sagger practice it might be said that thorough grinding and mixing of the constituents is to be recommended, as this would obviously tend to produce a more homogeneous structure. It is evident that due to the comparatively low temperature reached and the consequent high viscosity of the mass only a limited dissolving action can take place so that considerable flint may remain unacted upon or insufficiently combined.

In conclusion, the writer desires to express his thanks to the pottery firms who have coöperated by furnishing samples of frit.

NOTE ON THE LOAD BEHAVIOR OF ALUMINOUS REFRACTORIES¹

By A. V. BLEININGER

During the war it was found necessary to find for a certain purpose refractories more heat resisting than the average fire brick and as permanent in volume, under furnace conditions, as possible. For this purpose several mixtures were prepared and subjected to the load and fusion tests. These were based on the use of predominating amounts of high grade, calcined Pennsylvania flint clay and of artificially prepared sillimanite, consisting of 71.6 per cent of North Carolina kaolin and 28.4 per cent of anhydrous alumina, the latter being, of course, replaceable by the purer grades of bauxite. The sillimanite mixture, after thorough grinding of the raw constituents, was fired to a temperature of cone 20.

The plastic constituent was the usual fire clay employed as bond clay in the manufacture of flint clay brick in Pennsylvania, admixed with an equal part of North Carolina kaolin, or kaolin alone. It was thought that in this way the heat-resisting power of the brick could be improved, since usually the bond clay is the weak link in refractories of this type.

The first of these mixtures was molded into standard size bricks by the soft-mud process and all the others by dry-pressing, employing a pressure of 5000 pounds per square inch. The firing of the bricks was carried either to cone 14 or 16.

In order to bring about exceedingly severe conditions the usual temperature of the load test was raised from 1350° to 1400° C, except for mixture 1, for which the temperature of 1350° was retained. The pressure maintained was 50 pounds per square inch. The contraction is expressed in per cent of the original length of the brick.

The fusion test was conducted in the usual manner, employing a pot furnace with natural gas as fuel and with compressed air

¹ By permission of the Director, Bureau of Standards.

at 40 pounds per square inch. The extreme temperature limit which could be reached was cone 35.

The results of this work are compiled in the following table:

| No. | Composition. | | | Kaolin % | Temp. of firing Cone | Firing shrink- age % | Contraction in load test at 1400° C % | Cone at softening point |
|-----|-----------------------------|--|------------------------------|-------------|-------------------------------|-------------------------------|---|-------------------------------|
| | Calc. flint clay % | Arti- ficial sill- man- ite % | Plastic fire clay % | | | | | |
| 1 | 75 | .. | 12.5 | 12.5 | 14 | 1.06 | 2.40 (1350° C) | 33 |
| 2a | 80 | .. | 10 | 10 | 14 | 0.47 | 2.80 | 33 |
| 2b | 80 | .. | 10 | 10 | 16 | 0.35 | 0.84 | 33 |
| 3 | 80 | .. | .. | 20 | 16 | 0.83 | 0.88 | 35 |
| 4 | .. | 80 | 10 | 10 | 16 | .. | 0.61 | above 35 |
| 5 | .. | 80 | .. | 20 | 16 | .. | 0.48 | above 35 |

From these results it appears that refractories high in alumina can be produced which resist load conditions and are practically constant in volume. The main requisite is that the burning temperature be carried sufficiently high. This is shown quite strikingly by the mixture 2a and b, where the increase in the firing temperature from cone 14 to 16 reduced the contraction in the load test from 2.8 to 0.84 per cent.

With reference to the use of synthetic sillimanite it is obvious that the calcination temperature must be carried high enough so that the mixture is really transformed into the compound in question, a point readily determined by microscopic examination. The failure of certain bauxite refractories in use undoubtedly is due to the neglect to realize that practical permanence of volume at furnace heats cannot be reached unless both the calcination of the aluminous ore and the firing of the bricks are raised to the proper temperature. This point can be established with accuracy for every mixture by means well known to ceramists and may be lowered by the addition of small quantities of such fluxes as boric acid. It is likewise essential that the kaolin and alumina or bauxite be ground together intimately before calcination so that the close physical contact necessary for the formation of sillimanite may be brought about.

It should be realized also that the molding of the bricks by dry-pressing assists not only in lowering the shrinkage in burning but the deformation under load conditions as well.

Refractories higher in alumina, therefore, are not inherently deficient in ability to assist load conditions; but it is evident that deformation under pressure depends largely upon the previous thermal history of the specimen. If it has already been caused to contract by sufficiently high calcination and burning it will resist compression within the limits required by practice. Since the present work was carried only to an alumina content corresponding to that of sillimanite this conclusion cannot as yet be extended to mixtures still higher in alumina, owing to the fact that sillimanite and mixtures higher in silica might possibly possess greater rigidity at furnace temperatures than more aluminous combinations. It is believed that synthetic sillimanite produced by proper heat treatment can be developed to form a very useful type of refractory for severe heat conditions.

The writer desires to acknowledge his indebtedness to Mr. F. A. Kirkpatrick for his assistance in the preparation of the specimens.

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CERAMIC ABSTRACTS

General

A comparison of the heat insulating properties of some of the materials used in fire-resistive construction. W. A. HULL. Bureau of Standards, *Tech. Papers*, 130, (1919).—This investigation was preliminary to the investigation of fire-resistive properties of full-sized building columns, and was made for the purpose of determining the heat insulating properties of materials commonly used as protective coatings for steel. It was found that in clay specimens the rate of heat progress was comparatively rapid in hard burned samples but slow in soft burned ones, the porosity and density being important factors. In concretes the principal variable is the aggregate, and but little difference is indicated as to the ability of concrete of various aggregates to protect reinforcing steel placed near the surface. Greater differences are shown as to the final temperature attained near the center of the specimens and in the strength left in the mass of concrete after the test. These indications are somewhat favorable to slag concrete and particularly so to limestone concrete. The showing of gravel concrete, on the other hand, is somewhat unfavorable in respect to temperature attained in the interior and distinctly so in respect to the strength of the concrete after testing, although these results are not conclusive at the present time. Gypsum specimens showed relatively slow temperature progress and also low strength after test.

H. G. SCHURECHT

Comments on the constitutional formula of kaolin and other silicates. R. WEGSCHEIDER. *Z. Elektrochem.*, 21, 22, 352 (1919).—While the majority of chemists understand the complex silicates as salts of polysilicic acid, in which the silicon atoms are combined with each other through the oxygen, one occasionally sees formulas in literature in which a direct combination of the silicon atoms are given. Such are the cases with the formulas of Simmonds (*Chem. Zentr.*, 1904, 1, 77) and of Pukall (*Ber. Deutsch. Chem. Ges.*, 43, 2105 (1910)). These formulas were already criticized by Manchot (*Ber. Deutsch. Chem. Ges.* 43, 2603 (1910)) upon good grounds. Manchot states that the combinations between the silicon atoms in silicon-oxygen combinations, takes place only in reducing conditions, while silicates are formed without reduction. In inorganic combinations between silicon atoms the products are unstable, especially those containing oxygen. Silicic ethane is strongly reducing and the silicic oxalic acids are very explosive. Formulas with direct combined silicon atoms would not explain the staple condition of kaolin. If one has direct combined silicon atoms in silicates one is forced to believe that the oxygen atoms are directly combined. It is known, how-

ever, that such combinations are unstable also as hydrogen peroxide, organic peroxides, etc., which are strongly oxidizing liberating oxygen. Regarding silicates as salts of polysilicic acid does not prevent one from regarding those containing aluminum as salts of aluminium silicic acid with oxygen combinations between Si and Al.

H. G. SCHURECHT.

Ovens and kilns with a high thermal efficiency. A. BIGOT. *Trans. Cer. Soc.*, 18, 276-318.—See abstract "Furnace for High Temperatures," this JOURNAL, 1, 498.

A. J. LAMBERT.

PATENTS

Water purification. W. O. SNELLING. U. S. 1,325,213, Dec. 16, 1919. The base-exchanging property of zeolites has been utilized in the softening of water. The inventor transformed ordinary Portland cement into artificial zeolites by hydration and subsequent treatment with solutions of alkali-metal compounds. The cement is hydrated by boiling in water and is then agglomerated by another portion of cement. The calcium content is then withdrawn, say by means of acid. The transformation into zeolite is completed by boiling in a sodium carbonate solution. The product is said to be an efficient water-softening agent and may be regenerated like ordinary zeolites by treatment with strong hot solution of sodium chloride.

Alumina process of recovering. C. G. MINER. U. S. 1,324,318, Dec. 9, 1919. Alumina, substantially uncontaminated by silica, is obtained from aluminous silicates, such as the potash-bearing feldspars, leucite, sericite, etc., by comminuting the silicate and sintering with an alkali metal carbonate, then digesting with caustic alkali to dissolve the alumina and thus precipitating the alumina by carbonating the solution at boiling temperature to avoid substantial precipitation of silica.

G. E. MIDDLETON.

Geological

The Chinastone and fireclay leases, hundred of Dudley, Kangaroo Island. R. L. JACK. Dept. of Mines, South Australia. *Review of Mining Operations* for half-year ended June 30, 1917, No. 26, 1917, p. 38.—The geology consists of sediments changed to phylites and micaceous schists and sandstone. These are cut by a pegmatite dike, the exact dimensions of which are unknown, but which appears from evidence shown by the workings to be at least 1000 feet long and 100 feet wide. Most of the work was done in search of gems, but upon the exhaustion of such minerals attention was directed to the china stone derived probably from the dike. High-grade fire brick was produced, and also a china stone, but owing to competition by imported materials the work was abandoned. Now, however, small amounts of china-stone are shipped at irregular times. The fire clay prospects are not in good condition and information concerning them is meager. The following analyses are given: Silica, SiO_2 , 70.20, 66.10; Alumina, Al_2O_3 , 18.90, 20.28; Ferric oxide, Fe_2O_3 , 1.02, 0.84; Lime, CaO , 0.08, 0.12; Soda, Na_2O , 2.58, 2.58; Potash, K_2O , 5.74, 8.76; Water at 100° C, H_2O , 0.04, 0.20; Water over 100° C, H_2O , 0.63, 0.30.

E. D. ELSTON

Refractories

Refractory and abrasive matter, a new called Corindite. A. BIGOT. Paris.—In 1914 a French engineer, N. Lecesne, took out a patent for a new process of fusing bauxite in a very economical manner. Bauxite is very abundant in France, being chiefly of the white and red variety.

| | White bauxite | Red bauxite |
|-------------------------------|---------------|-------------|
| Al_2O_3 | 59.2 | 60.10 |
| H_2O | 14.10 | 14.20 |
| TiO_2 | 3.50 | 3.30 |
| SiO_2 | 18.50 | 2.85 |
| Fe_2O_3 | 4.70 | 21.55 |

The Lecesne process consists in heating in a cupalo furnace a mixture of bauxite and anthracite by blowing air into the lower part. Before introduction of the charge a fire is started in the bottom of the furnace. The bauxite is reduced, aluminum carbide is formed, which, in the presence of air, is transformed almost entirely into alumina. The heat developed by the reaction is such that the mass goes into fusion by successive layers, a special contrivance preventing the matter from adhering to the sides of the cupalo. The operation terminated, the mass is cooled by means of surplus air, and a vesicular fused block is found, in which an immense number of small crystals are disseminated in the mass. The products are crushed and freed from metallic particles by means of a magnet and have the following analyses:

| | White bauxite | Red bauxite |
|-------------------------------|---------------|-------------|
| Al_2O_3 | 68.80 | 69.25 |
| TiO_2 | 3.85 | 3.70 |
| SiO_2 | 21.40 | 3.00 |
| Fe_2O_3 | 5.25 | 23.35 |
| Carbon..... | 0.60 | 0.50 |
| Loss on ignition..... | .10 | .15 |

The fused bauxite has been designated by the name "corindite" on account of the crystalline corundum. White bauxite is very refractory while red bauxite resembles emery and is a powerful abrasive. The fusion point of corindite is higher than 1950°C , being more refractory than the original bauxite. This is explained by the fact that iron oxide has almost entirely united to form the spinel $\text{Al}_2\text{O}_3\text{FeO}$. Corindite is bonded with finely ground refractory material as bauxite or kaolinitic clay. Brick are made either by hand or machine and are burned to $1350^\circ\text{--}1400^\circ\text{C}$. Brick made in this way expand slightly at $1700^\circ\text{--}1730^\circ$ and above 1750° shrink slightly, having a shrinkage of 3 per cent at 1850° . The porosity depends on the manner of making and brick last much longer in practice than the unfused brick.

As an abrasive the red bauxite compares favorably with Naxos emery. The main difference between the two is that the Naxos emery contains lime which lowers the fusion point to 1600° while the red bauxite may be heated to 1700° without melting. Emery wheels can be burned to 1500° with red bauxite,

which is impossible with the Naxos emery. Red bauxite is not as effective an abrasive as the artificial corundum owing to the lower content of alumina (70 per cent) as compared with that of artificial corundum (90-92 per cent).

H. G. SCHURECHT

Magnesite as raw material. THOMAS CROOK. *Trans. Ceram. Soc.*, **18**, 67-145 (1919).—The siliceous magnesite of Baudissero in the Piedmont is reported to have been used quite successfully in porcelain manufacture previous to the beginning of the 19th century. This particular magnesite was at that time regarded as a high-class china clay (*terra da porcellana*) and was not known to contain any magnesia. The essential features of the manufacture of refractory magnesia is as follows: (1) The finished products, whether as sinter obtained by dead-burning the raw magnesite, or as bricks produced by a second or further burning of the pulverized compressed sinter, should consist essentially of crystalline magnesia. The Austrian practice aims at obtaining a sinter containing at least 83 per cent of magnesia. Lime, silica and alumina are regarded as undesirable ingredients and should not exceed 5 per cent, 6 per cent, and 2 per cent, respectively. Iron oxide is regarded as a desirable ingredient, but the amount of ferric oxide is not allowed to exceed 11 per cent or so of the sinter. (2) The dead-burning of the raw magnesite should be effective, since it is only the inert and comparatively dense, crystalline product (*periclase*), into which caustic magnesia becomes transformed by prolonged heating at temperatures upwards of 1400° C, that can be regarded as refractory. The kiln temperature required varies with, and must be adapted to, the nature of the raw material. The temperature required for the sintering of Styrian magnesite is said to range from 1400° C to 1600° C, the average being about 1500° C, while that required for Grecian magnesite is stated to be much higher. (3) The production of good magnesia bricks demands the use of pulverized sinter of good quality. The sizing of the grains, the nature and proportionate amount of the binder used where such is necessary, the pressure under which the bricks are moulded, the drying conditions, are controllable factors, and appear to be taken carefully into account in the Austro-Hungarian process of brick manufacture. The aim in this process seems to be to secure bricks the volume-shrinkage of which in the final burning operation does not exceed about 15 per cent, and the nature of which renders them immune from any considerable shrinkage under the furnace conditions for which it is designed to use them. The best way to classify magnesites is on the basis of texture and composition as follows: 1. Spathic breunnerite (*e. g.*, Styrian, Austrian); 2. Spathic magnesite (*e. g.*, Quebec, Washington, and Norwegian); 3. Compact magnesite (*e. g.*, Grecian, Californian, Italian, Indian (Salem) and Australian). Deposits of spathic magnesite or breunnerite usually contain much more impurity than those of compact magnesite. Breunnerite is usually coarse in texture, and characterized by a considerable percentage of ferrous carbonate isomorphously mixed with the magnesium carbonate. Spathic magnesite is usually less coarse in texture, and is almost free from admixture with ferrous carbonate. Spathic

magnesite and breunnerite generally occur in association with dolomite, and are, therefore, liable to contain much lime impurity. The admixture of this dolomite is less intimate in coarse-textured spathic breunnerites of Austria, than it is in the closer-textured spathic magnesite of Quebec. Partly for this reason, and partly owing to the isomorphously mixed ferrous carbonate, the dressing of breunnerite and elimination of the dolomitic impurity is economically more feasible than in the case of the purer spathic magnesite. Producers of the raw material seem to expect that the return of normal conditions will permit the Austrian exports to dominate the refractory magnesia market as in the past. One of the most important of the advantages that favor the Austrian export trade is the open-cast working of large deposits of breunnerite, the nature of which permits of the production of standard qualities of sinter at cheap rates. It would perhaps be unreasonable to expect that sintered magnesia should be produced at such a cheap rate under the less favorable mining conditions prevailing in Greece, Italy, India and California. Elaborate discussions of the mineralogical characteristics and geological occurrence of various magnesia minerals are given. A. J. LAMBERT

Some notes on silica and other refractory bricks made from non-plastic materials. G. W. MOTTRAM. *Trans. Ceram. Soc.*, 18, 148-53 (1919).—The economical kiln is one of large capacity, running up to 100,000 bricks. Satisfactory results in making fire brick were obtained with 90 per cent grog and 10 per cent fire clay, when the raw clay was ground to a fine slip with two or three times its weight of grog and the resulting mixture afterwards mixed with the remainder of the ground grog. Bricks made on this principle from calcined Stourbridge fire clay showed no contraction after repeated burning, and after a week's exposure in the port of an open-hearth steel furnace came out with the edges quite sharp. Le Chatelier gives the results of tests of bricks made by a similar process in a French works. (1) With all fine material the crushing strength reached 4,540 pounds per square inch. (2) With coarse grains passing 100-mesh, and retained on 120-mesh, 993 pounds per square inch. (3) With fine + graded grains up to $\frac{1}{3}$ inch the average was 3,095 pounds per square inch. All these bricks were burned at 1300° C. The durability of bricks made on this system, in the same works, from similar material, and used under similar conditions, was some 200 to 300 per cent in excess of bricks made with the usual method of grinding. A. J. LAMBERT

Furnace for testing fire brick under load at high temperature. C. H. LOVEJOY. *Chem. Met. Eng.*, 22, 109.—Description of a load test furnace for fire brick in use at the Pittsburgh Testing Laboratory, with plans for building furnace. The main difference between this furnace and type outlined by American Society for Testing Materials lies in the manner of applying load and the means of determining load during failure of brick under test. Pressure is applied by means of a spring, which carries brick to ultimate failure, determines variation in load sustained by brick at higher temperatures and gives rate of failure. A pressure of 50 pounds per square inch is

used, which is double that recommended by the A. S. T. M. The pressure is obtained through blocking, passing through bottom of furnace. The flame is led out through a chamber in back of furnace to prevent burning off of outlet pipe. Rate of heating is 500°C in first hour and up to 1350°C in five hours with this temperature maintained for one hour. Poor brick start to fail at as low as 950°C or 1000°C . Such brick show complete failure below 1200°C , the spring having returned to its original length with the load reduced to zero. Load remains constant in test and different rates of heating for different grades of brick are suggested. Fair brick will start to fail at about 1100°C and the spring will have about 25 pounds pressure per square inch left on them at 1350°C . First class brick will generally show no signs of failure before 1200°C , and many will stand 1300°C before starting to fail. Only two bricks were found which would show no sign of failure at 1350°C . All brick fail below 1500°C .

R. R. DANIELSON

Refractory product problems. A. BIGOT. Paris.—Publication by the author. When refractories are heated to high temperatures there is a certain group which change in volume either shrinking as clay refractories or expanding like silica refractories, while another group show practically no volume change when heated to high temperatures. In the pamphlet products with a constant volume are discussed, these being divided into natural mineral refractories and artificial minerals. Under the group of refractories made from natural minerals we have (1) spinels, principally the iron chromium spinel, (2) natural corundum (emery), and (3) zircon.

Chromite, FeOCr_2O_3 , comes chiefly from New Caledonia, Canada, Siberia, and Greece. Brick are burned to 1500° and show little shrinkage when burned to 1700° . The other spinels are the magnesium-alumina and the iron-titanium spinel which, however, are comparatively rare. Iron chrome brick are excellent refractories, being especially resistant to slag action.

Natural corundum consists of a mixture of alumina (95–98 per cent) with silica. It is obtained chiefly from Madagascar, India and South Africa. The brick are burned to 1400° and show little shrinkage when burned to 1700° . The softening temperature is not far below 2000° . Experience in using these brick in a Martin furnace revealed the fact that they were readily attacked by lime forming fusible aluminates and silico-aluminates.

Zircon from Madagascar contains about 33 per cent SiO_2 and 66 per cent ZrO_2 and 1 per cent impurities. To make brick 3–6 per cent kaolin or 3–4 per cent lime are used as a bond and the brick are burned to 1500° . When burned to 1750° they showed only a small shrinkage and the softening point is above 2000° . The presence of lime and iron oxide influence the softening point considerably. For instance, a mixture of 83 parts zircon, 5 parts lime and 12 parts iron oxide melts at 1830° . A mixture of kaolin (1800°) and zircon (2000°) may be obtained which softens at 1450° . In this manner it behaves similar to glucinum oxide which has a softening point of 2300° and a mixture of this oxide with kaolin melts at 1450° . Zirconia, ZrO_2 comes chiefly from Brazil. In purification it is treated with hydrochloric acid which

dissolves the iron and manganese. A product containing 98-99 per cent ZrO_2 may finally be obtained and this is calcined to a high temperature in an electric furnace before use. This material has a fusion point above 2000° and is used to make small special pieces as crucibles, tubes, and so forth.

Carborundum refractories (SiC) are good conductors of heat and are very resistant to sudden temperature changes. This material, however, is not very staple above 1500° when it decomposes(?). Fused quartz (1750°) is used chiefly for receivers, tubes, muffles, etc., and its use for other purposes is limited. Artificial corundum is prepared by melting bauxite in an electric furnace. It may also be prepared by the Leccesne and Gowen cupalo process.

Fused clay or kaolin may also be prepared by the cupalo process. This material is extremely compact and is obtained by heating sufficiently high enough to cause fusion. The density is increased about 20 per cent and the porosity decreased about 25 per cent. This material stands up about twice as long as that made in the ordinary way. Magnesite when treated by the Leccesne cupalo process is also extremely compact and shows little shrinkage when heated to $1700^\circ C$. The cupalo process is adapted for the calcining of quartz, dolomite and a number of other minerals. H. G. SCHURECHT

Study of silica products (Part II, bricks, etc.). A. BIGOT. *Trans. Ceram. Soc.*, **18**, 165-181. (Compare abstract "Silica Products," this JOURNAL, **1**, 582.)—Physical tests are carried out: (A) On products such as proceed from factories. (B) On the same products submitted to the temperature 1710° for an hour or two, or to 1650° for the time necessary for their complete expansion. *Density*: If the absolute density is not less than 2.45-2.50, it is certain that the burning has neither been high enough nor long enough; if this density is below 2.40 and tends to approach 2.35, then the burning can be considered satisfactory. Silica products based on compact flint present smaller absolute density, which should approach 2.25 and tend toward 2.22. *Porosity*: Varies from 8 to 20 per cent. The porosity should decrease when the products are heated to 1710° . *Resistance to crushing at ordinary and high temperatures*: Tests after heating at 1710° are made on whole bricks. After this burning, if softened or deformed, or melted, the brick are of inferior quality. Where they have resisted, three principal cases occur: (1) As the temperature is raised, the silicious grains increase in volume and porosity; the cement which surrounds them is partially vitrified, contracts and resists (without cracking) the expansion of the silica grains. The porosity of these products decreases in proportion as they are taken to higher temperatures, and the best silica products present this peculiarity. (2) Porosity has increased and the products are cracked and friable; the large grains of rock have expanded too much and have broken the cement. (3) Porosity after heating to 1710° has slightly increased, resistance to crushing at ordinary temperatures has perceptibly decreased, and resistance to crushing at 1500° has become zero. These grains of silicious rock have become friable, the chief material employed being such as falls into powder at 1710° ; the cement which enwraps them has preserved its consistency and has not

cracked. This maintains in the product a certain resistance to crushing at ordinary temperature; but at 1500° the cement softens and, the grains no longer having any cohesion, the products are crushed under an insignificant pressure. A Fremont machine, modified by Bodin, is used for measuring crushing strength at all temperatures up to 1500° C. Refractory products fall in two classes: (1) Those of which the crushing resistance presents a maximum at about 1000°. (2) Those which do not present a maximum. In the first category must be ranged kaolins, clays, bauxites, silica products, products with carborundum as a basis, etc. In the second category should be placed products of chromite, Euboean or Styrian magnesia and so forth. In the first class until the culminating point is a little exceeded the material is crushed and ground to bits; in the descending part of the curve the material is flattened and behaves partly or wholly like a plastic substance. *Burning of the products:* 1600° C should be approached as near as possible. At this temperature a few hours' firing suffices to obtain a good result. This temperature can be reached in car tunnel kilns of Bigot's design. *Silica bricks which have been in Martin furnaces:* Bricks show three very distinct zones, D, E and F. The upper zone, D, is constituted by the unattacked silica brick. The intermediate zone, E, is brown; it includes, disseminated in its mass, white silica grains, analogous to those of the part D, and of which the size decreased in proportion as the lower part, F, is approached. These white grains are attacked by degrees by the brown matter which surround them; this attack is produced at their external surfaces, but, if they are attacked, the brown material penetrates to the interior of the cracks and the attack becomes more rapid. The lower zone, F, is grey; it no longer contains white silica grains, visible to the naked eye. The lower surface of this grey part, in direct contact with the furnace atmosphere, is brilliant and covered with a kind of brown glaze; it is hollowed in time by partial fusions which were produced there by contact of the dust and slags of the furnace. Bricks proceeding from basic or acid furnaces have analogous compositions and physical properties. The means of two series of analyses are:

| | Silica | Lime | Magnesia | Iron oxide | Alumina | Manganese oxide |
|--------------|--------|------|----------|------------|---------|-----------------|
| Grey part... | 84.60 | 3.55 | 1.05 | 9.25 | 0.60 | 0.95 |
| Brown part.. | 78.45 | 4.95 | 1.15 | 13.10 | 1.20 | 1.15 |

Cones of D and F and decimal standard 173 (1730° C) were bent in the same manner, though cone E, formed of brown material, melted like glass and was completely absorbed by its refractory support. The brown material E did not pass through the pasty condition like the materials D and F, but melted and liquified abruptly. The foreign matters, proceeding from the slags or the dust of the furnace, simply choke up the pores in the expanded parts of the bricks where they penetrate by capillarity, forming the brown material. Chemical action of the foreign materials begin as soon as impregnation is established. Examined under the microscope, the grey and brown parts present a complete transformation of the silica into cristobalite and tridymite. At 1500° C the grey part, F, resists a load of 138 kilog. per sq. cm. This is superior to that of all other refractories known. A. J. LAMBERT

Refractory materials of South Wales, notes on the. J. ALLEN HOWE. *Trans. Ceram. Soc.*, 18, 27-42 (1919).—The refractory raw materials of South Wales, silica rocks, fire clays and dolomitic limestones are practically all obtained from the carboniferous strata. Up to the present time the silica rocks are the most extensively exploited. The first Dinas brick in the world were made in South Wales almost 100 years ago. The name "Dinas" is derived from a rocky eminence, the *Craig-y-dinas*, situated not far from Hirwaun, South Wales. The principal source of material is the Basal Grit layer of the Millstone Grit formation. The type of rock most in favor is a hard, compact, fine-grained quartzite with a buff, purple or blue tinge of color. This fine-grained stone may pass into one of more friable nature or into one containing pebbles of quartz. In some cases a hard form of pebbly quartzite is rejected; in others it is used along with the finer kind for silica brick. A certain amount of the incoherent grit may also be employed for the same purpose or for furnace sand. The rocks employed for silica brick are fairly uniform in their microscopic characters. They consist essentially of angular and subangular grains with silica cementation. The grains in most samples average 0.1 to 0.2 mm. diameter, but in others they are slightly larger with occasional small pebbles of quartz and chert. A small amount of mica is present in most samples and in some very little feldspar is observable; a little iron stain may exist between the grains of quartz and argillaceous matter in small amounts is sometimes present. Analyses of typical rock gives: 97.5-98.15 SiO_2 ; 0.40-0.70 Al_2O_3 ; 0.40 Fe_2O_3 ; 0.30-0.40 TiO_2 ; 0.20-0.30 alkalis and less than 0.10 each of other impurities. Various grades of fire clay and dolomitic limestone are found in the district.

A. J. LAMBERT.

Swansea district, science in relation to the industries of the. COSMO JOHNS. *Trans. Ceram. Soc.*, 18, 1-14 (1919).—This article deals with the metallurgical and correlated metallurgical refractories industries in the district centering around Swansea, Wales. Among important natural resources are: abundant supplies of coals ranging from long-flame bituminous to extremely pure anthracite; slightly calcareous sands, suitable for hearths of copper refining furnaces; refractory sand for the manufacture of Dinas brick; and pure limestone for metallurgical uses. The manufacture of Dinas brick is the principal ceramic industry. Fire clays of high grade may exist but up to the present have not been discovered in the district. The need of a research institution in the district is emphasized.

A. J. LAMBERT.

The corrosive action of flue dust on firebricks. J. W. MELLOR AND W. EMERY. *Trans. Ceram. Soc.*, 18 (1919).—This paper records the results of experiments consisting of mixing various kinds of flue dust and salts with a flame impinging on various types of fire brick. In general, the penetration by dusts is greater in fire clay than in silica fire bricks. In most cases the bond is attacked first and the coarser grains last. In silica bricks the depth of penetration by the dust is generally less the finer the grain. In the fine-grained bricks the coarser grains and the bond are both attacked, while in the coarse-

grained bricks the bond is alone attacked to any serious extent. It, therefore, follows that the bond of a silica fire brick offers the feeblest resistance to the attack of a corrosive slag. The attack on the coarser grains of silica fire brick varies with the nature of these grains. When there is much cementing material between the quartz grains the penetration of the rock fragments by the dust is greater than in the case of a compact rock made up of interlocking grains. Under oxidizing conditions iron oxide does not corrode silica bricks to any noteworthy extent, but under reducing conditions ferrous silicate forms and acts as a corrosive flux. In the trials with "bull dog" the silica bricks are far less attacked than fire-clay bricks; and generally the iron oxides corrode fire-clay bricks more than they do the silica bricks. The dusts apparently exert an influence on the conversion of the quartz into the low specific gravity form or forms even where the coarse grains have apparently not been penetrated. When the dust is such that it can form a surface glaze the brick is protected from further attack, or rather the subsequent rate of attack is considerably diminished. This corresponds with a well-known practice of smearing a glaze mixture on the face of the brick work in certain kilns. If the surface glaze be fluid enough and in such a position that it can flow to a lower level these remarks do not apply, for the brick is rapidly eaten away as soon as the glaze begins to drip. The attempts to give the brick a resistant face by fusing the surface by means of a blowpipe flame are not satisfactory because the surface skin peels off.

A. J. LAMBERT.

The standardization of tests for refractory materials. II. *Trans. Ceram. Soc.*, Report of Special Committee, pp. 251-263.—The use of standard lawns established by the Institute of Mining and Metallurgy are recommended. For elutriation separations a modified Schöne apparatus is specified. The results are reported in terms of surface factors. Preliminary specifications are given for a test of the corrosive action of flue dust on refractories.

A. J. LAMBERT.

Zirconia: Its occurrence and application. H. C. MEYER. *Trans. Ceram. Soc.*, 18, pp. 264-275.—See abstract "Zirconia," *J. Am. Ceram. Soc.*, 1, 838.

A. J. LAMBERT.

PATENTS

Refractory composition. E. T. FERNGREN. U. S. 1,324,546, Dec. 9, 1919. For crucibles and glass pots a composition is used comprising equal parts of calcined zirconium oxide, calcined or fused magnesite and a calcined high-grade alumina clay, the whole bonded with about 20 per cent German pot clay. If a more refractory composition is desired, the zirconium oxide is increased, while for furnace linings not in contact with molten material as low as 15 per cent raw zirconium oxide may be used. A poreclain body to which is added 15 per cent raw zirconium oxide and 7 per cent calcined magnesite is tough, elastic, non-conductive of electricity and not liable to cracking when subjected to sudden temperature changes. The zirconia, magnesia, alumina, and bonding clay may be fused, granulated and then bonded with a plastic clay.

G. E. MIDDLETON.

Glass

PATENTS

Glass-drawing bait. H. F. CLARK. U. S. 1,324,229, Dec. 9, 1919. The inner surface of this bait is provided with a plurality of grooves, so arranged that the glass held thereby cannot loosen. The objectionable air leakage at this point is thereby avoided and the danger of breakage in taking down the drawn cylinder is reduced.

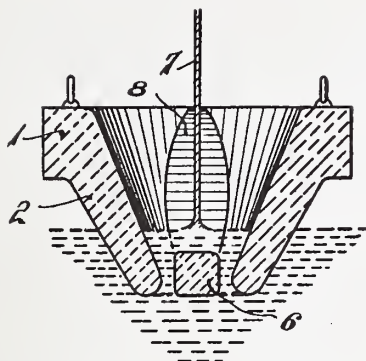
Glass, reinforced—and method of making it. C. AND V. SHUMAN. U. S. 1,324,361, Dec. 9, 1919. A sheet of celluloid is placed between two sheets of glass and the whole subjected to pressure at a temperature high enough to soften the celluloid and cause it to unite firmly to the glass sheets. The operation is carried out under reduced atmospheric pressure for the purpose of removing the air from between the glass and celluloid.

Glass, method and machine for gathering. K. E. PEILER. U. S. 1,324,464, Dec. 9, 1919. The gathering head is thrust into the fluid glass in the melting furnace and rotated so as to gather a mass of glass simulating hand gathering. It is then withdrawn from the furnace to an auxiliary hot chamber, wherein the glass accumulated on the head is allowed to slump or shed down from the head, in the heat of the chamber so that the desired quantity for a mold charge can be separated by gravity, aided by shears when necessary, and discharged while it remains in the most suitable condition for further manipulation.

Glass-furnace, apartment tank. W. M. MATHEWS. U. S. 1,324,917, Dec. 16, 1919. This is a regenerative, muffle furnace for making flint glass, those kinds of glass which contain large proportions of lead oxide and which cannot successfully be made in open pots. There are three longitudinally adjacent tanks, heated from above through thin muffle arches. Each may be drained into an adjacent refining chamber and each serves in turn as a melting, plaining and flowing tank.

Glass-furnace, regenerative. W. N. MATHEWS. U. S. 1,324,918, Dec. 16, 1919. There are two longitudinally adjacent muffle refining chambers which communicate at one end with a single melting chamber and at the other with a single cooling chamber.

Glass-drawing apparatus. H. K. HITCHCOCK. U. S. 1,324,965, Dec. 16, 1919. A refractory drawing basin 2 is immersed in the molten glass and terminates in a drawing slot. This slot is partly closed by means of a longitudinal refractory bar 6, which protects the glass in the basin and the sheet being drawn from the radiant heat of the mass of molten glass. For this reason the main body of the glass may be maintained at a higher temperature than would otherwise be feasible with consequent reduction of string, stone and rheam. The greater viscosity of the glass immediately above the



bar 6 operates to keep the sheet being drawn at the center line of the basin.

Furnace, glass tank. L. T. SHERWOOD. U. S. 1,325,172, Dec. 16, 1919. Water boxes are maintained in close contact with the outer surfaces of glass tank walls at the glass level. The walls thus cooled do not disintegrate so rapidly as they otherwise would.

Glass cane and glass tubing, apparatus for drawing. C. H. QUACKENBUSH AND J. C. SMEDLEY. U. S. 1,325,265, Dec. 16, 1919. An improved cooling chamber surrounds the tube being drawn, extending from the working level a considerable distance along the tube. As the tube is drawn from the working level of the glass in the pot falls, the cooling chamber automatically descends with it.

Glass-blank forming machine. J. RAU. U. S. 1,325,331, Dec. 16, 1919. A single valve mechanism controls the various parts of the machine in operation at the same time locking and unlocking the table on which the molds are mounted. It automatically opens the operating compressed air ports.

Glass shaping and blowing machine. A. WILZIN. U. S. 1,325,388, Dec. 16, 1919. This is a glass blowing machine in which the glass is introduced into the parison mold from above. The subsequent operation of molding stretching and blowing the parison, and of cooling and ejecting the finished bottle are performed automatically.

Glassware-transferring machine. J. P. MINGLE. U. S. 1,325,527, Dec. 23, 1919. This is a machine designed for handling glass fruit jars produced by that kind of machine which delivers the jars in an inclined or horizontal position, this machine operating to feed these jars to an off-bearing belt in an upright position.

Glass letters, apparatus for forming. E. C. GMELIN. U. S. 1,325,785, Dec. 23, 1919. A flat metal plate having the form of desired letter depressed therein constitutes the main member of the mold. This plate is supported

so that flames circulate beneath it and heat it uniformly. A sheet of glass is placed upon it and heated. As the glass is heated it softens and tends to fill the cavities which define the letter. At this stage a male die member is utilized to press the glass to the bottom of these molds.

Lamp manufacture. W. L. VAN KEUREN. U. S. 1,326,121, Dec. 23, 1919. This is an improvement in the sealing-in operation. The stem with its flare is placed within the neck of the lamp in the usual position. The lamp is rotated, its neck heated and the elongation and contact with the flare effected by means of a gravity-actuated pull-down fork. By this means the glass in the neck is thinned out uniformly. During this operation a pin on the stem support keeps the exhaust hole in the flare open. G. E. MIDDLETON.

White Ware and Porcelain

Apparatus for the charging and drawing of potters' ovens. M. P. FERNEYHOUGH. *Trans. Ceram. Soc.*, 18, 154-164 (1919).—The apparatus (Eng. Pat. 13,387, 1915), falls essentially into the following parts: A gantry of hoist, detachable transport arms or stages, and the outer standards. Saggars which are conveyed on trucks can be run to the oven mouth, raised by the lift and transported to the desired place in the oven. In like manner trucks convey loaded saggars when fired, across the arms, when they are lowered and run into the saggar-house. The hoist, which is built up of steel bars, of angle and other sections, is telescopic and adapted to be brought into a small compass. The sides are detachable. This will permit the hoist to be readily brought within the oven, or withdrawn as the case may be. The transport arms or stages are telescopic. There will be occasions when a short arm only will be required, *e. g.*, at the commencement of the drawing, and at the conclusion of the placing. As the top saggars are removed it will be necessary for the man to work towards the rear of the oven, in which case the arm can be lengthened, so as to save time and labor. The outer standards can be used either extended or when closed. For the drawing of the oven their use is optional. They will not be required except perhaps at the end, but during the placing operations it will be necessary to bring them into service extended to their full length all the time. A. J. LAMBERT.

PATENTS

Base for supporting molded plastic articles. D. H. APPLGATE, JR. U. S. 1,324,535, Dec. 9, 1919. Molded clay products such as bath tubs, glass pots, and so forth, are formed and dried on a sectional base, the sections being free to move as the article shrinks. Cracking is thus minimized.

Colloidal and finely subdivided substances, process of treating. B. SCHWERIN. U. S. 1,326,106, Dec. 23, 1919. The adsorbed components of colloidal, soluble or finely divided matter are separated from the adsorbing components by subjecting the colloidal matter, dispersed in a suitable medium, to electro-osmosis where by the adsorbed and adsorbing components separate and migrate through porous diaphragms of selected materials having a central anode and an outer concentric cathode. Clay may be cleansed of ad-

sorbed colloidal iron hydroxide by this method. U. S. 1,326,104 and U. S. 1,326,105 also relate to the treatment of colloids by electro-osmosis.

Clay, treatment of. W. FELDENHEIMER. U. S. 1,324,958, Dec. 16, 1919. This is a process of removing impurities from clays, such, for example, as fine quartz and micas from china clays, by suspension and sedimentation. In working with Fraddan clay a 5 per cent suspension is made and deflocculated by a sodium carbonate solution (1.5 per cent sodium carbonate based on the clay present). The supernatant suspension is allowed to remain in the settling tank not more than four hours. It is then decanted into a second tank and flocculated by an aluminum sulphate solution (1.5 per cent aluminum based on the clay present). The flocculating solution is added slowly. The suspension is allowed to remain in the second tank about four days or as many days as the hours required for deflocculation. Tannic acid may be employed as a deflocculator followed by H_2SO_4 as a flocculator. G. E. MIDDLETON.

Cement and Lime

Portland cement, the solubility of, its relation to theories of hydration. J. C. WITT AND F. D. REYES. *Concrete* (C. M. S.), 16, 13 (1920).—It is common experience that water in which cement test pieces are stored soon contains substances in solution. It becomes soapy to the touch and has an alkaline reaction. Tests will reveal the presence of $Ca(OH)_2$, $Al(OH)_3$, sulphates, silicates of lime and alumina, and other compounds. The experimental work reported in this paper was very carefully and accurately carried out. Commercial cements were shaken with water for various lengths of time, and the amount of elemental Ca present in the water determined:

TABLE 1.—ANALYSES OF CEMENTS

| | A | B | C | D |
|-----------------------|-------|-------|-------|-------|
| Loss on ignition..... | 2.43 | 2.15 | 2.17 | 3.24 |
| SiO_2 | 22.60 | 21.40 | 21.26 | 20.62 |
| Al_2O_3 | 7.72 | 7.58 | 8.54 | 6.62 |
| Fe_2O_3 | 1.76 | 1.70 | 2.08 | 2.56 |
| CaO | 61.32 | 62.94 | 62.82 | 63.50 |
| MgO | 1.08 | 1.37 | 1.13 | 1.43 |
| SO_3 | 1.45 | 1.61 | 1.02 | 0.82 |
| $K_2O + Na_2O$ | 1.63 | 1.14 | 1.17 | 1.33 |

TABLE 2.—FIRST SERIES. CALCIUM DISSOLVED FROM ORIGINAL CEMENTS DURING SHAKING WITH CARBON DIOXIDE-FREE WATER.

| | A % | B % | C % | D % |
|---|--------|--------|--------|--------|
| Total calcium (Ca) present | | | | |
| per gram of cement..... | 0.4383 | 0.4499 | 0.4490 | 0.4539 |
| First period, 20 hours..... | .0665 | .0808 | .0843 | .0681 |
| Second period 16 hours..... | .0071 | .0125 | .0089 | .0259 |
| Total for 426 hours..... | .1644 | .1741 | .1729 | .1594 |
| Total calcium dissolved (per cent)..... | 37.51 | 38.69 | 38.50 | 35.12 |

A second series was run using those portions of the cements which had been air-separated by a Goreham fluorometer using an air pressure corresponding to 20 millimeters of mercury. No attempt was made to measure the size of grain. The analyses of the separated portions and the results obtained are shown in tables 3 and 4.

TABLE 3.—ANALYSES OF CEMENTS AFTER AIR SEPARATION

| | A | B | C | D |
|---|-------|-------|-------|-------|
| Loss on ignition..... | 3.91 | 3.73 | 3.55 | 5.00 |
| SiO ₂ | 20.48 | 20.22 | 18.96 | 18.40 |
| Al ₂ O ₃ | 7.81 | 7.17 | 9.58 | 8.95 |
| Fe ₂ O ₃ | 2.37 | 2.11 | 2.32 | 2.03 |
| CaO..... | 61.14 | 62.38 | 61.84 | 62.20 |
| MgO..... | 1.22 | 1.30 | 1.42 | 1.34 |
| Na ₂ O + K ₂ O..... | 1.07 | 0.64 | 0.63 | 0.87 |
| SO ₃ | 1.97 | 2.43 | 1.62 | 1.27 |

TABLE 4.—SECOND SERIES. CALCIUM DISSOLVED FROM FINE CEMENT BY SHAKING WITH CARBON DIOXIDE-FREE WATER

| | A | B | C | D |
|----------------------------------|--------|--------|--------|--------|
| Total calcium (Ca) present | | | | |
| per gram of cement..... | 0.4369 | 0.4458 | 0.4419 | 0.4445 |
| Ca dissolved per gram of cement: | | | | |
| First period, 1 day..... | .1282 | .1432 | .1519 | .1535 |
| Second period, 1 day..... | .0072 | .0147 | .0091 | .0113 |
| Total, 15 days..... | .1664 | .1805 | .1749 | .1759 |
| Percentage of total calcium | | | | |
| that goes into solution..... | 38.09 | 40.49 | 39.58 | 39.57 |

The main difference between this series and the first is the much greater amount of calcium going into solution during the first period—about double. The time necessary for completion was much shorter and the percentage of the total calcium present was higher. The total amounts of the other elements in solution are negligible in comparison with the calcium.

There is no important increase in the amounts of these constituents in solution after the first period of shaking. By using a sufficiently large volume of water per gram of cement, from 87 per cent to 92 per cent of the calcium in a cement was found to go into solution in 24 hours. The bearing of this work on the theories of hydration of cement is discussed in connection with the work of Richardson, Michaelis, Rankin, Klein and Phillips, and others. The following summary is given: The factors that affect the results are (a) absence of CO₂; (b) method of agitation; (c) fineness of grain; (d) volume of water; (e) time. Volume of water is the most important. The effect of temperature has not been studied. As the volume of water is increased, the amount of calcium going into solution in a given time increases rapidly. When cement is treated with approximately 8000 times its weight of water, 90 per cent of the calcium present goes into solution in 24 hours, with indications that still more would dissolve in a greater volume. Though the work

was not undertaken as a study of hydration, the results obtained are closely related to the theories of hydration that have been formulated from time to time. Since all the important compounds in cement contain calcium, and 90 per cent of the calcium present goes into solution, it may be stated that under favorable conditions the hydration of all important compounds results in the formation of $\text{Ca}(\text{OH})_2$. It has not been found possible to obtain a saturated solution of $\text{Ca}(\text{OH})_2$ by shaking cement in water. The presence of dissolved $\text{Ca}(\text{OH})_2$ may inhibit further hydration, or it may be that when the concentration of the $\text{Ca}(\text{OH})_2$ solution reaches a certain value, a colloid is formed according to the theory of Michaelis. F. A. KIRKPATRICK.

Plaster, the setting of. C. H. DESCH. *Trans. Ceram. Soc.*, **18**, 15-22 (1919). —Le Chatelier's account of the setting process is accepted. On mixing the burnt plaster with water each particle soon becomes surrounded by a layer of a solution which is saturated with regard to the hemihydrate, but strongly supersaturated with regard to the stable gypsum. Crystallization of gypsum soon begins, either spontaneously or more probably from nuclei which have persisted unchanged throughout the burning process. Growth of the crystals taking place from many neighboring centers, radiating groups are formed, and the interlocking of these is at least one of the causes of the strength of the mass. Another aspect to be considered is that all recent work on metals goes to show that boundaries between neighboring crystal grains in a mass of pure metal or homogeneous alloy are surfaces of strength. This may be attributed to the existence of surface tension in the boundaries, or to the presence of a layer of amorphous material, chemically identical with the crystals, between the surfaces of the latter. The reconversion of the hemihydrate into gypsum is accompanied by a decrease of volume. The apparent expansion is caused by the outward thrust of the lath-shaped crystals during their growth. Recent work goes to show that the difference between the supposed modifications of anhydrite are largely due to mere differences in the fineness of the particles. In experiments of Keane, gypsum which had been heated for some time at 600° was ground so that the average diameter of the particles was 0.05 mm. and then behaved as a dead-burnt plaster, being unable to set. The same product, ground until the average diameter was reduced to 0.005 mm., set rather rapidly, forming a hard mass. For the ceramic industry the principal requirement of a good plaster for moulds is porosity and strength. Many salts accelerate the setting, especially the soluble sulphates, while others, including borax, retard it. Generally, the accelerators are substances which increase the solubility of gypsum (or, more probably, of the hemihydrate), while retarders are substances which diminish the solubility. Assuming that the failure to make good plaster by re-burning old moulds is due to the absorption of soluble salts during use, thus completely altering the setting properties, it should be possible to wash out the salts from the coarsely broken material before submitting to re-burning. Such a washing process is applied in the manufacture of plaster from such gypsum deposits as those found in some parts of South Australia, containing a large pro-

portion of soluble salts. It would be necessary to grind the burnt plaster very finely before use.

A. J. LAMBERT.

PATENTS

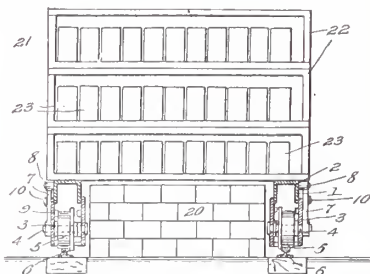
Cement, process of obtaining, and soluble potassium compounds. C. ELLIS. Reissue 14,773, Dec. 23, 1919. Original U. S. 1,186,522, June 6, 1916.

G. E. MIDDLETON.

Brick and Tile

PATENTS

Brick-handling machinery. C. E. ROSS. U. S. 1,325,864, Dec. 23, 1919. After the bricks leave a cutting machine they are placed upon the pallet sections 21 of refractory clay, and these sections are mounted upon the truck in the manner shown, which sections are so formed that they may be arranged in superposed relation without bringing the bricks into contact with each other. In this loaded condition, the truck is pushed or otherwise conveyed to the kiln, and the assemblage of bricks and pallet sections are deposited upon the foundation 20 by lowering frame 2, so that the lower-most section rests directly upon the relatively broad upper face of said foundation. It



will be observed that owing to the width of the foundation, the pallet structure will be securely supported and all strain and stress entirely removed therefrom. The shorter vertically extended portions of each section form substantially solid vertical side walls, which materially increase the strength of the pallet structure and effectually prevent the latter from bending or warping when subjected to heat and weight. After the kiln has been thus filled, the bricks are burned and the truck again run into position beneath the assemblage of pallets and bricks and by operating the elevating mechanism of the truck, said assemblage is removed from engagement with the foundation and may be thus transported to any suitable position of removal.

G. E. MIDDLETON.

Chemical Stoneware

On the standardization of chemical stoneware. HARALD NIELSEN. *Trans. Ceram. Soc.*, 18, 182-229 (1919).—The ultimate tensile strength of high class, English vitreous stoneware seems to vary between 600 and 800 lbs. per sq. inch, and material below this should not be used for chemical plant under

pressure. N. has found that a stoneware pipe calculated according to the simple formula: $w = \frac{p \times d}{2 \times u}$ where w = wall thickness in inches, p = pressure in pounds per sq. inch, d = diameter in inches, u = ultimate tensile strength in pounds per sq. inch, will stand the pressure required within the limits of u . The working safety margin should be reasonably large, and N. suggests 4 as the factor by which the w found by the formula should be multiplied. High pressure stoneware pipes of above 4 inches diameter should be avoided, partially because the wall thickness becomes rather heavy and drying difficult, and the chances of successful vitrification thus decreases. The most suitable flange-joint is the conical buttressed flange. In pipes for low pressure the wall should be made as thin as possible, and the limit should be strength necessary to stand carriage and handling. On no account should the glaze be relied upon to protect the actual stoneware from corrosion; unless the body itself is thoroughly vitrified, the glaze gives only a false sense of security. The strength of acid eggs or monte-jus can be calculated in precisely the same manner as the pressure piping, and the same formula can be used. The factor which governs the capacity of such vessels is the wall thickness required to resist the pressure. A vessel working under high pressure requires a very thick wall, and it becomes very difficult to produce such a vessel, as the wall will be difficult to dry and burn satisfactorily. Two and a quarter inches is about the limit for satisfactory working. A factor of safety for u of 2 is suggested. Instead of thin necks for inlet and outlets heavily bossed openings should be provided. Stoneware vessels should be as dense and vitreous in body as possible to avoid sweating. A preventive treatment is to fill the vessel before use with a strong sodium silicate solution for 24 hours; afterwards the vessel should be filled with acid, sulphuric or nitric, not too weak, for some few hours. Silicic acid separates out and fills the fine pores. A storage jar of $1\frac{1}{2}$ tons capacity was turned out, complete, in plaster of Paris molds, in 20 minutes by means of a huge jig. Two operators, one standing on each side of the machine, threw lumps of clay as fast as they could into the mold. The lumps were quickly smoothed and kneaded into the exact form by the scraper. In screw presses for pipes up to 8 inches in diameter, the die should be arranged horizontally so that the pipe is shot vertically upwards between guides. In this way fine surface cracks can be avoided, which are formed when the pipes are shot out horizontally on a table. In discussing this paper M. Barret stated that the suitability of the salt glaze for the chemical stoneware has been much over-rated and the popular opinion that this type of glaze is the "ideal" is untrue. Such glazes are frequently too alkaline and are almost invariably covered with a fine network of crazes. Better results are obtained by using a felspathic glaze of the porcelain type, the composition of which is under control and which can be modified to suit varying conditions.

A. J. LAMBERT.

JOURNAL OF THE AMERICAN CERAMIC SOCIETY

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EDITORIALS

TECHNOLOGIC MONOGRAPHS

The American Chemical Society is about to issue a series of technologic monographs. Each monograph is to cover one phase of chemical technology. The following description of what the board of editors of the proposed series consider a good monograph is of interest:

"The ideal monograph is a critical presentation of the topic which it treats, and gives the reader the present status of the knowledge of that topic in such a way that he need not consult prior literature except for details: it should show clearly which points are still uncertain and require further investigation and so act as an incentive to research by suggesting problems. The preparation of such a monograph implies that the author has first-hand knowledge of the topic treated and this implies in turn, particularly in the case of technologic monographs, that the topic chosen must not be too large. In other words, instead of a book dealing with a very broad general topic, we would prefer a number of more specific smaller topics, each written by a man thoroughly conversant with that particular phase. The board wishes to emphasize that the proposed series will aim to be critical in character, rather than mere compilations; and takes this ground because a number of existing monographs cover a field broader than the author was really familiar with, the result being that the book contains one or two good chapters but is largely a somewhat uncritical compilation of material."

There is need for a similar series of publications in the ceramic industries. It might be well for those intending to prepare monographs for these industries to study carefully the foregoing description. Some of the monographs on ceramic subjects issued in the past certainly have not complied with this.

A COMPENDIUM OF CHEMICAL AND PHYSICAL CONSTANTS

At a meeting of the Inter-Allied Chemical Conference held in London, July 14-17, 1919, there was formed an International Union of Pure and Applied Chemistry, and it was voted that "Critical tables of physical and chemical constants shall be published in the United States and there shall be created an American publication committee charged with the general organization and the prosecution of the work." It is proposed to issue a critical compendium of chemical and physical constants, which shall be up to date and correct; and which shall contain such new constants as can be determined before the time of publication as well as many which have been determined but which are not now generally available. This work has been undertaken by the National Research Council in coöperation with the American Chemical and the American Physical Society. The business arrangements are to be in the hands of a board of three trustees: Mr. Hugh K. Moore, chairman (appointed by the National Research Council); Mr. Julius Stieglitz, (appointed by the American Chemical Society); and Mr. Edward P. Hyde (appointed by the American Physical Society).

AMERICAN ENGINEERING STANDARDS COMMITTEE

After almost three years of painstaking investigation and discussion by the engineering fraternity the revised constitution of the American Engineering Standards Committee, along with the by-laws and rules of procedure, has been adopted, and has been ratified by the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, and the American Society for Testing Ma-

terials, and the three Government Departments of Commerce, Navy and War. Each of these interests have three representatives, and although the Committee as it exists today consists of twenty-four members, the new Committee is of very wide scope and allows the direct or indirect participation of anyone interested in standardization.

The American Engineering Standards Committee makes it possible to give an international status to approved American engineering standards and to coöperate with similar organizations in other countries. Similar organizations are now functioning in Great Britain, France, Switzerland, Holland and Canada.

Through the new Committee the methods of arriving at engineering standards will be unified and simplified and, by coöperation, the duplication of standardization work will be prevented. Standards will not be created without giving all interested an opportunity to participate.

Any organization may request the Committee to approve standards which it has formulated, or to approve committees that it has appointed, and by so doing becomes a sponsor society. Two or more organizations may act as joint sponsors. Approval of a standard is given when it is the substantially unanimous conclusion of a section committee made up of representatives of producers, consumers and general interests, and so selected that all interests concerned have adequate representation on the section committee.

The "approval" of a standard by the American Engineering Standards Committee does not mean that the Committee has itself worked over and approved each detail, but rather that the work has been carried out by a sectional committee adequately representing the industry concerned, and sponsored by one or more bodies of ability, experience and standing, so that the result may stand for what is best in American engineering practice.

ORIGINAL PAPERS AND DISCUSSIONS

ADDRESS OF THE RETIRING PRESIDENT THE NEED OF TECHNICAL ASSISTANCE IN THE BRICK INDUSTRY

By R. T. STULL

Considerable progress has been made in the clay industry within the last half century but it has not maintained the pace with progress made in many other industries. The plea for the need of research in glass by Dr. Washburn and that of Mr. Purdy for research in refractories appearing in the November issue of the JOURNAL, are both excellent and timely. However, an analysis of the situation reveals the fact that the same urgent need for research exists in practically all other ceramic industries and more especially does this need exist in the clay industries.

The value of all ceramic products¹ in round numbers amounts to \$500,000,000 per annum. Of this sum approximately \$250,000,000, or one-half, is represented by clay products. The value of brick of all kinds, including common, face, paving, ornamental, enamel and fire-brick is placed at approximately \$120,000,000. The value of brick, therefore, represents about 24 per cent of the value of all ceramic products and 48 per cent of all clay products. Brick represent the largest item in value of all the different ceramic products.

The industry is composed of a large number of comparatively small units and the number of plants representing the investment

¹ The value of all ceramic products is given as \$447,000,000 in *J. Am. Ceram. Soc.*, 1, 372. The value of all clay products reported in "Clay-working Industries and Building Operations in the Larger Cities in 1917" by Jefferson Middleton, U. S. G. S., is given as \$248,023,368 and the value of brick of all kinds gives a total of \$118,076,507.

f a million dollars or more can be counted on the fingers of one hand.

The date when brick making began is unknown and the industry has played an important part in history throughout the ages down to the present time. At present the industry is carried on in every state of the Union and in our foreign possessions. From the points of value, extent and distribution of the industry, brick are bound to exercise no small influence upon the economic life of mankind.

Approximately 70 per cent of the cost of production of brick is about equally divided between fuel and labor; an extravagant use of these two commodities such as no other industry would very long tolerate.

Advancements have been made but these advancements have been confined principally to both ends of the process while the middle has been marking time. At the beginning of the processes, mining the clay by steam shovel or planer, its transportation, grinding, screening and pugging are practically automatic. At the finishing end the continuous and tunnel kilns have made it possible to save from 40 to 70 per cent of the fuel as compared to the intermittent kiln. However, from the cutting table on through the process until the brick are delivered to the stock piles, the movement of material is almost entirely dependent upon hand labor.

There is no end to the problems needing investigation in order to learn the "how" and "why" but that most needed in the brick industry today is "mechanical assistance."

After the brick leave the cutter they are hacked by hand on dryer cars. When dry they are taken from the dryer cars and set in benches in the kiln. After the firing process has been completed and the brick cooled, they are taken from the benches, sorted and hacked on wheelbarrows or trucks. The brick are conveyed to the stock pile or freight car and again handled for the fourth time.

The first auger machine was made over fifty years ago and up until a few years ago it was stated that this same machine was still making brick. The auger moulding machines, built since the appearance of the pioneer have been constructed along the same

lines of their predecessor. The improvements over their forerunner have been confined principally to increase in size, strength and capacity and have been constructed along lines of better proportions, but the fundamental principles of auger knives and barrel have remained unchanged.

Approximately 60 per cent of the power applied to the moulding machine is lost in friction and resistance of the auger and knives in cutting through the clay or churning it around in the barrel and as long as we are dependent upon an auger for forcing the clay through a die, just so long will it be necessary to contend with laminations.

It is not impossible to develop a moulding machine in which all the power expended is utilized in moulding the clay column except that necessarily lost in the friction of the bearings, and which can mould a clay column substantially free from laminations. If such a machine can be developed it must necessarily be a radical departure from the present auger machine.

The two principal requirements that a shale or clay must possess in order to make a successful paving brick are long vitrification range and ability to make brick which will meet the requirements of the rattler test. There are a large number of clays and shales of long vitrification range but which laminate so badly when moulded on the auger machine that they will not withstand the rattler test. The development of a moulding machine capable of moulding a clay column substantially free from laminations would broaden the manufacture and uses of paving brick and develop the industry in localities now remote from good paving brick clays. It would also make possible the moulding of stiff mud fire-brick of better structure.

The moulding, drying and firing of brick are simple operations as compared to more complicated things done by automatic machinery in other industries. It is true that automatic setting machines are in successful operation, setting brick in scove or open top kilns, but a successful machine for closed kilns remains to be developed. Numerous patents have been issued on automatic hacking machines, but their practical worth is still a question, since they have not been put into practical operation. A brick plant was built several years ago to eliminate hand labor,

but the success of this plant has evidently not been considered sufficient to warrant the building of other plants along the same lines.

All these experiments and investments are commendable and good in that they are the necessary pioneers in the course of development. The first automobiles were unreliable as to movement, since they might run a few miles or only a few feet and stop without apparent cause and require a half day's tinkering before they would start again. But they were the pioneers representing progressive steps leading to the almost perfectly operating automobiles of today.

The time will come when brick will be made automatically without being touched by human hands throughout the process of manufacture. It will require years of painstaking experimental work and require the expenditure of many thousands of dollars.

The modern bottle blowing machine has done more to advance the glass bottle industry than any other single achievement. Its development required a number of years and the expenditure of over half a million dollars. Its development, however, was made possible by the wisdom and foresight of a capitalist who was willing to furnish the necessary financial backing. There is no brick manufacturing corporation large enough or willing to "tie up" the necessary capital over the period of years required in perfecting the automatically operated brick plant.

The modern automobile is a wonderful machine made up of a number of intricate parts. It is not the invention of one man but represents the best thoughts and efforts of hundreds of men, each contributing his part to the many intricate details woven together into a harmoniously operating machine. Thus it will be with the automatically operated brick plant of the future. It will not represent the inventive talent of one or two men but the best efforts of many mechanical, electrical and ceramic engineers and practical brick makers.

When a number of inventors are working independently and more or less secretly in developing certain mechanical phases of an intricate process, it means more or less duplication of work and requires a long period of time before these inventions can be sifted and the best features brought together and formed into a synchronized and practically working unit. Such development also

involves patent conflicts and delays in securing control of certain desirable patented features.

The retail price of brick has nearly trebled in the last ten years and the bulk of this increase in price is due to the increased cost of fuel and labor. Very little has been done in the last decade to reduce the cost of these two items and that which has been done has not been fully taken advantage of by the brick industries.

If the retail prices of brick are to be appreciably reduced and still leave a fair margin of profit to the manufacturer, it is obvious that the cost of production must also be reduced. Since 70 per cent of the cost of production is chargeable to fuel and labor, reduction in the cost of production must be made largely in the cost of these two items. The only solution to the problem appears to be the development of automatic machinery and the improvement of the continuous or the tunnel kiln.

The evolution of the industry, if left to itself, will be slow and the total sum expended will represent a huge sum. In the meantime the market price of brick must be governed largely by the conditions of fuel and labor.

There seems to be one of two possibilities by which the problem may be solved efficiently, economically and in the shortest possible time. First, that the enterprise be financed by a capitalist or corporation not afflicted with "cold feet" or impatience and willing to finance the enterprise to the limit. Second, the formation of a development corporation composed of a large number of brick companies and sufficiently capitalized to meet the necessary experimental requirements. A plant should be set aside as an experimental plant or, what would perhaps be better, to build an experimental plant on a sufficiently large scale to work out the process in a practical way.

In planning such an enterprise, we must not lose sight of the value of research of the physico-chemical nature. The experimental plant and the research laboratory should be combined, for many problems will arise of the "how" and "why" nature which must be solved in the laboratory. The big problem is that involving mechanics, but when the "modern brick plant of the future" is finally evolved, it will be found that no small part will have been contributed by the research laboratory.

MAGNESITE REFRACTORIES

By J. SPOTTS McDOWELL,¹ AND RAYMOND M. HOWE²

Authors' Note

The technical press of the past generation contains a large number of papers dealing with refractory magnesite, scattered throughout various periodicals. While these are of great value, many of them are not readily available to the average reader, and their range is in most cases narrow. There is not a single treatise in which the subject has been treated as a whole from a modern point of view.

In compiling the material herein presented, the authors have endeavored to survey the salient facts in the entire field pertaining to the occurrence, preparation and properties of magnesite for refractory use. Most of this material has been taken from the available technical literature, which has been drawn upon for whatever was considered to be of permanent value or of particular interest at the present time. Abundant references in footnotes, and a bibliography are included. Acknowledgment is due the Research Laboratories of the Harbison-Walker Refractories Co. and of the Mellon Institute of Industrial Research for such data as are here published for the first time. The authors wish to express thanks to Kenneth Seaver, Dr. E. W. Tillotson, R. D. Pike, W. F. Rochow and Dr. C. R. Fettke for their critical review of the manuscript.

Introduction

The mineral magnesite enters into the preparation of a variety of products. Its chief use is in the manufacture of refractory materials, since its chemical properties and high refractoriness render it particularly suitable as furnace linings for various metal-

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lurgical operations. For refractory purposes it is sold in the form of brick, of finely ground "furnace magnesite" for brick laying, and of dead-burned grains for making and repairing furnace bottoms. The grains are a mixture of granules varying in size from pieces of about $\frac{5}{8}$ inch in diameter to very fine but gritty particles.

While magnesite is an important refractory in the metallurgy of copper, lead and nickel, and for electric, heating and welding furnaces in the steel industry, its principal application is in the basic open-hearth steel furnace. The hearth of the furnace, according to well-established American practice, is usually built up of magnesite brick and dead-burned grain magnesite, so laid that the brick base is protected by a working bottom of the granular material. The latter, mixed with 10 to 15 per cent of granulated open-hearth furnace slag, is sintered into place in layers $\frac{1}{2}$ to 1 inch thick to a total depth of 12 to 18 inches at the center of the furnace.

Magnesite enters also into the production of the following materials: Oxychloride or Sorel cement, from which exterior stucco, flooring, and other structural materials are made; fireproof paint; CO_2 gas; metallic magnesium; magnesium chloride; magnesium sulphate (Epsom salt); basic carbonate of magnesia, used as a heat insulator for boilers, pipes and so forth, as a toilet preparation, and for various other purposes; wood pulp for the sulphite process; minor miscellaneous products.

PART I. HISTORICAL NOTE ON THE DEVELOPMENT OF MAGNESIA REFRACTORIES IN STEEL MAKING

While the widespread adoption of magnesia as a furnace refractory is a development of the last generation, considerable experimental work had been done much earlier. As early as 1860 when the Bessemer process was being introduced in Europe, Tunner of Leoben, Austria, suggested the use of calcined magnesite for converter linings, although his suggestion had nothing to do with the dephosphorizing of steel.¹ In 1864 A. Frank prepared magnesia from magnesium chloride solution and made

¹ Harbord and Hall, "Metallurgy of Steel," published by J. B. Lippincott Co., 1916, p. 58.

brick therefrom, which was employed in the bridge-wall of a furnace. The practice was soon given up because there was no demand for such brick.¹

According to a paper published in 1867 by A. Schwartz, magnesia brick was being used at that time in Donawitz near Loeben, Austria, in puddle furnaces and for other refractory purposes. The bricks were made by mixing ground magnesite with a small amount of refractory clay and burning at a rather high temperature. They gave good service in the bridge-wall of the puddle furnace. At ordinary temperatures they had to be carefully protected from moisture, since their high lime content caused slaking.

Caron,² in France, had made experiments to determine the practicability of adopting magnesia in the making of crucibles and refractory brick, and for lining reverberatory steel-melting furnaces, and in 1868 published a paper on the subject.³ The material used in his experiments was the amorphous magnesite from the Greek Island of Euboea. He succeeded in making brick by mixing one part of lightly calcined magnesite, as a bond, with six parts which had been calcined at white heat, moistening the mixture with 10 to 15 per cent of water, and molding under a very high pressure. He also made small magnesia crucibles and found that they could be exposed to the air for a long time without injury. The value of the light-burned magnesite as a bond resulted from its property of setting and hardening when moistened with water and later dried.

About 1870 the attempt was made in England to melt steel in small magnesia crucibles, but without success. The crucibles stood the heat well so long as they were kept empty and in the furnace, but fell to pieces when taken out of the fire. Three or four years later Muller & Co., near Paris, made some magnesia linings intended for service in the Bessemer converters of the Creusot Steel Works, and suggested the adoption of magnesia in

¹ Robert Sherer, "Der Magnesite," published by A. Hartleben, 1908, p. 83.

² Jno. Percy, "Metallurgy," published by Murray, London, 1875, p. 135.

³ *Compt. rend.*, 66, 839 (1868).

the hearth of the Siemens furnace. The suggestion seems to have been carried out, for at the meeting of the Iron and Steel Institute in May 1879, C. W. Siemens announced¹ that several years earlier he had employed magnesia brick in an open-hearth furnace. He considered it a splendid lining, but found it very expensive and had given it up because the slag acted on it more rapidly than was desirable.

The discovery of Thomas and Gilchrist, made public in 1879,² that phosphorus can be eliminated from steel by proper treatment in a basic lined vessel, focussed the attention of steel men upon the great need for a satisfactory basic refractory, and led to numerous independent investigations. The first basic Bessemer and basic open-hearth furnaces were lined with dolomite; and although it was soon found to possess serious defects as a refractory material, its use to a minor extent has continued to the present day. It was employed in the calcined condition for hearth linings and for the manufacture of brick by bonding with tar.

In the early eighties considerable work was done in Germany in the attempt to produce satisfactory magnesia linings, and in the spring of 1882 magnesia brick was being offered for sale in that country.³ About that time German bricks were being made from magnesia artificially prepared from dolomite; difficulties were encountered, however, on account of its lack of bonding power, and the brick was too expensive to compete with the dolomite-tar brick.⁴ Experiments with dead-burned Grecian magnesite grains for furnace bottoms also gave unsatisfactory results. The material utilized was too refractory to sinter together properly at furnace temperatures, and patches of the bottom often came up and floated in the bath.⁵ When a sufficient amount of

¹ *J. Iron Steel Inst.*, 14-15, 153 (1879).

² Thomas and Gilchrist, "On the Removal of Phosphorus," *Ibid.*, 14-15, 120 (1879). Geo. W. Maynard, "The Introduction of the Thomas Basic Steel Process in the U. S.," *Trans. Am. Inst. Mining Eng.*, 41, 280 (1910).

³ *Stahl u. Eisen*, May, 1882, advertisement.

⁴ T. Egleston, "Basic Refractory Materials," *Trans. Am. Inst. Mining Eng.*, 14, 455 (1885-6).

⁵ "Magnesia and Dolomite as Basic Refractory Materials," *J. Iron Steel Inst.*, 28-29, 894 (1886).

such material as clay was added to form a strong bond, the refractoriness was greatly lowered. These difficulties were overcome when it was found that a crystalline magnesite from Styria, by reason of its high content of iron, had the property of sintering into a hard, dense mass without fusion.¹ This material when dead-burned, could be manufactured into dense, strong brick of high refractoriness, and used for the construction of open-hearth furnace bottoms which were highly resistant to the erosion of molten metal and the action of slags. The Styrian magnesite by 1887 had almost completely displaced all others for lining furnace bottoms, and until early in the late war maintained this supremacy. In the late eighties, the use of grain magnesite in place of dolomite for open-hearth furnace bottoms increased rapidly in continental Europe,² although dolomite continued to be employed at a great many plants, particularly in England. It has been stated that in 1888, fifty pounds of magnesia or 150 pounds of dolomite were required per ton of steel produced.

Imports of magnesite into the United States began in 1885 with a shipment of 800 tons of crude Austrian (Styrian) magnesite brought in by the Otis Steel Company, who made use of it in the following year at their plant in Cleveland in the first basic open-hearth experiments made in America. After dead burning the magnesite, it was utilized to line a 15-ton open-hearth furnace previously operated as an acid furnace; the bottom was built up by ramming a mixture of dead-burned magnesite and tar into place. The experiment was not a commercial success, and the use of magnesite was given up.³

Carnegie, Phipps & Co. began the successful manufacture of basic open-hearth steel at Homestead in 1888. Early in that year the following prices per gross ton were quoted for magnesite delivered at New York: Brick \$38.00; dead-burned magnesite \$16.00; crude magnesite \$9.00.⁴ Large importations did not

¹ K. Sorge, "Magnesia and Its Use as a Basic Refractory," *Stahl u. Eisen*, 7, 850 (1887).

² "The Use of Magnesite for Basic Linings," *J. Iron Steel Inst.*, 43, 315 (1890); "Magnesite in Open-Hearth Linings," *Stahl u. Eisen*, 10, 222 (1890).

³ G. W. Maynard, "Introduction of Basic Open Hearth Steel in the United States," *Trans. Am. Inst. Mining Eng.*, 41, 289 (1910).

⁴ A. E. Hunt, "Recent Improvements in Open Hearth Steel Practice," *Ibid.*, 16, 718 (1887-1888).

begin until 1898, when 16,000 tons were brought in. Since that time, with the rapid increase of basic open-hearth steel production in this country, the use of magnesite as a refractory has greatly increased, and the United States now consumes about 70 per cent of the world's output. In the years immediately prior to the war over 90 per cent of the magnesite consumed in the United States came from Austria, being imported in the form of dead-burned "grains." This material was employed for the manufacture of brick, and also, without further treatment, for the construction of open-hearth furnace bottoms.

To meet the shortage brought about by the cessation of shipping from Austria early in the war, magnesite was imported from Greece and Canada, domestic deposits were developed, and dolomite was substituted for magnesite wherever practicable. The deposits of this country are now developed sufficiently so that an adequate present supply is available, and ample reserves are in sight to last many years. The following table shows the amount of magnesite produced in the United States and imported since 1911, and the great expansion of domestic production since 1914.

TOTAL MAGNESITE CONSUMPTION OF UNITED STATES ON A CALCINED BASIS

| Year | Net tons | | | Tonnages reduced to calcined basis assuming 2.1 T. crude = 1 T. calcined | | |
|-----------|--------------------------------|-----------------------|----------|--|----------|---------|
| | Domestic ^a Crude | Imported ^a | | Domestic | Imported | Total |
| | | Crude | Calcined | | | |
| 1911..... | 9,375 | 12,974 | 122,075 | 4,463 | 128,253 | 132,716 |
| 1912..... | 10,512 | 17,905 | 125,252 | 5,006 | 133,778 | 138,784 |
| 1913..... | 9,632 | 13,235 | 167,094 | 4,587 | 173,396 | 177,983 |
| 1914..... | 11,293 | 13,354 | 121,817 | 5,378 | 128,176 | 133,554 |
| 1915..... | 30,499 | 49,764 | 26,574 | 14,423 | 50,271 | 64,794 |
| 1916..... | 154,974 | 75,345 | 9,270 | 73,797 | 45,148 | 118,945 |
| 1917..... | 316,838 | 30,277 | 3,966 | 150,875 | 18,384 | 169,259 |
| 1918..... | 231,605 | 5,432 | 19,049 | 110,228 | 21,636 | 131,924 |

^a Figures taken from reports of United States Geological Survey.

At the beginning of the war, the refractories manufacturers were crippled by a lack of calcining facilities, since the Austrian material had been imported in the calcined condition; the low iron content of the available magnesite caused additional difficulties. In order to confer the proper sintering and bonding properties, it became necessary to add iron oxide and to incor-

porate it thoroughly by burning at an extremely high temperature. Magnesite thus treated, when sufficiently low in harmful impurities, is a high-grade refractory and gives entirely satisfactory service.

PART II. CRUDE MAGNESITE¹

Mineralogy.—The mineral magnesite, when pure, is composed of 47.6 per cent magnesia and 52.4 per cent carbon dioxide. It is one of the calcite group of rhombohedral carbonates, which closely resemble each other in crystalline structure, symmetry and cleavage. The members of this group of interest in this connection are the following:

| Mineral | Formula | Specific gravity | Theoretical analyses | | | |
|--|--|------------------|----------------------|------|------|-----------------|
| | | | MgO | CaO | FeO | CO ₂ |
| Calcite..... | CaCO ₃ | 2.72 | .. | 56.0 | .. | 44.0 |
| Dolomite..... | CaCO ₃ ·MgCO ₃ (a) | 2.85 | 21.7 | 30.4 | .. | 47.8 |
| Magnesite..... | MgCO ₃ | 2.90-3.08 | 47.6 | .. | .. | 52.4 |
| Magnesite, var. breun- nerite(b)..... | Mg(Fe)CO ₃ | 3.08-3.20 | .. | .. | .. | .. |
| Mesitite..... | 2MgCO ₃ ·FeCO ₃ | 3.35-3.36 | 28.2 | .. | 25.3 | 46.5 |
| Pistomesite..... | MgCO ₃ ·FeCO ₃ | 3.42 | 20.0 | .. | 36.0 | 44.0 |
| Siderite..... | FeCO ₃ | 3.83-3.88 | .. | .. | 62.1 | 37.9 |
| Ankerite(c)..... | CaCO ₃ · (MgFe)CO ₃ | 2.95-3.10 | 10.0 | 28.0 | 18.0 | 44.0 |

(a) Normal dolomite. Varieties occur in which the ratio of the two carbonates is not 1:1.

(b) Composition variable.

(c) Composition variable—analysis given is for normal ankerite.

Other related minerals, not of the same crystallographic group, are:

| Mineral | Formula | Specific gravity | Analysis | | |
|-------------------|---|------------------|----------|-----------------|------------------|
| | | | MgO | CO ₂ | H ₂ O |
| Hydromagnesite... | 3MgCO ₃ ·Mg(OH) ₂ + 3H ₂ O | 2.15-2.18 | 43.9 | 36.3 | 19.8 |
| Brucite..... | Mg(OH) ₂ | 2.38-2.40 | 69.0 | .. | 31.0 |

Magnesite does not form an isomorphous series with calcite or dolomite; consequently, when it contains calcium carbonate

¹ L. C. Morganroth, "The Occurrence, Preparation and Use of Magnesite," *Trans. Am. Inst. Mining Eng.*, **50**, 890 (1914); Thomas Crook, "Magnesite as Raw Material," *Trans. Ceram. Soc. (Eng.)*, **18**, 67 (1918-19). This paper describes all the well known magnesite deposits of the world.

the latter is present as included grains of dolomite, which can often be removed by mechanical processes. Magnesium and iron carbonates, however, form a continuous isomorphous series, and the variety of magnesite known as breunnerite is an isomorphous mixture of the two containing a variable percentage of iron carbonate. Crook¹ has suggested that when the iron carbonate content is less than 5 per cent the mineral should be termed magnesite, and that the term breunnerite be used when the iron carbonate content is between 5 and 30 per cent.

Two types of magnesite are to be distinguished; the crystalline and the dense or cryptocrystalline. The former, which includes breunnerite, is often termed spathic magnesite. It varies from finely to coarsely crystalline in texture, and has a hardness of $3\frac{1}{2}$ to 4; it is easily broken up and ground, especially when of coarse texture. The color is white, yellowish, blue-gray to drab, red, pink, black or mottled. It is seldom found pure, but usually contains slight admixtures of iron, lime, silica and sometimes a small amount of manganese. The color cannot be used as an index of the purity; colored magnesites of Washington, for example, are often very pure.

The cryptocrystalline variety, usually spoken of as amorphous magnesite, is the more common type. It is fine grained and compact, showing no cleavage. In color it is usually snow-white, but is sometimes light to pale orange-yellow or buff, due to the presence of impurities. The fracture is conchoidal to uneven, and the hardness $3\frac{1}{2}$ to 5. The presence of several per cent of silica, caused by inclusions of serpentine, quartz, chalcedony, opal, and so forth, is not uncommon. The lime and iron contents are usually low, although a few deposits are known in which the FeCO_3 content is as high as 4 per cent. In general, amorphous magnesite is somewhat purer than the crystalline variety.

The specific gravity of the dense variety of magnesite is 2.90 to 3.00, averaging about 2.94 when pure. Cleavage fragments of pure crystalline magnesite have a specific gravity of 3.02; values of 3.08 or higher indicate the presence of ferrous carbonate. The average specific gravity of breunnerite is 3.08 to 3.13.

¹ Thomas Crook, *op. cit.*, p. 75.

Dissociation of Mineral Carbonates.—When heated to a high degree a gradual decomposition of the carbonate minerals takes place, with the evolution of CO_2 . At any given temperature each mineral has a definite dissociation pressure, which increases with the intensity of the heat. The temperature at which it becomes equal to 760 millimeters of mercury, or one atmosphere, is known as the dissociation point. Decomposition of the minerals begins and under proper conditions can be carried to completion at a much lower heat than this, if the CO_2 evolved is carried off. However, in the calcination of such minerals as magnesite under industrial conditions, a considerably higher temperature than the dissociation point is required to remove all the CO_2 . The temperature necessary is dependent upon the size of the lumps, the texture of the mineral, the amount and character of impurities, and the duration of the heating.

Montgomery and Groves¹ found that on heating pure precipitated CaCO_3 a loss in weight of 2.35 per cent per hour occurred at $620\text{--}627^\circ\text{C}$, of 4 per cent per hour at 647°C , and that after 15 hours at 647°C the CO_2 was completely driven off. The dissociation point of calcium carbonate² has been given by different observers as 880°C (limestone),³ 886°C ,⁴ 898°C ,⁵ 910°C ⁶ and $913\text{--}923^\circ\text{C}$.⁷ Johnston's determination of 898°C is probably the most accurate. His figures for the dissociation pressures of CaCO_3 in millimeters of mercury are given below:

¹ Montgomery and Groves, "Note on Determination of Several Dissociation Points," *Trans. Am. Ceram. Soc.*, **18**, 214 (1916).

² E. H. Riesenfeld, "The Decomposition of Carbonate of Lime," *J. Chim. Phys.*, **7**, 561 (1908); *Chem. Abstracts*, **4**, 982 (1910).

³ Bleining and Emley, "The Burning Temperature of Limestones," *Trans. Am. Ceram. Soc.*, **13**, 618 (1911).

⁴ De Forcrand, "Carbonates of the Alkalis and Alkali-earths," *Compt. rend.*, **146**, 511 (1908).

⁵ John Johnston, "The Thermal Dissociation of Calcium Carbonate," *J. Am. Chem. Soc.*, **32**, 938 (1910).

⁶ D. Zavreiff, "The Dissociation of Calcium Carbonate," *Compt. rend.*, **145**, 428 (1907); *J. Chim. Phys.*, **7**, 31 (1908); *Chem. Abstracts*, **3**, 1112 (1909).

⁷ J. A. Hedvall, "Formation and Decomposition Temperatures of the Carbonates of Strontium, Barium, Calcium and Magnesium," *Z. anorg. allgem. Chem.*, **98**, 147 (1916).

| ° C | Pressure | ° C | Pressure |
|-----|----------|------|----------|
| 500 | 0.11 | 850 | 373.0 |
| 600 | 2.35 | 898 | 760.0 |
| 700 | 25.3 | 900 | 773.0 |
| 750 | 68.0 | 950 | 1490.0 |
| 800 | 168.0 | 1000 | 2710.0 |

Working with materials carefully prepared and purified by precipitation, O. Brill¹ found that magnesium carbonate begins to dissociate at 237° C under a pressure of one atmosphere of CO₂; evolution of CO₂ takes place in steps, forming a series of basic carbonates with different dissociation temperatures. The final member of this series, 7MgO.CO₃, dissociates completely at 510° C. These results are not comparable with determinations made on the natural mineral magnesite.

According to Hedvall² the dissociation pressure of magnesite reaches one atmosphere at 531–570° C. Wülfing³ found that in a furnace kept at a constant temperature of 500° C magnesite lost less than half its CO₂ in two hours, and that not all the CO₂ had been driven off in 12 hours. Kallauner⁴ reports that amorphous magnesite begins to dissociate at about 500° C, and that CO₂ is evolved very rapidly at 620° to 625° C. He finds also that the dissociation of normal dolomite begins at 500° C, increases rapidly with rising temperature and reaches a maximum between 710° and 730° C; from 730° to 870° C dissociation is slow, but it increases above 870° C and reaches another maximum at 900° to 915° C. CaO did not appear in the heated material below 875° C. It was believed that the dolomite, MgCO₃·CaCO₃, began to separate into its components MgCO₃ and CaCO₃ at about 500° C, that the MgCO₃ formed dissociated rapidly at 710°–730° C and that dissociation of the CaCO₃ began at 870° C.

The dissociation temperature of siderite is 100° to 150° C

¹ O. Brill, "The Dissociation of the Carbonates of the Alkaline Earths and Magnesium," *Z. anorg. Chem.*, **45**, 275 (1905).

² *Op. cit.*

³ E. Wülfing, 1900, as quoted in Doelter's "Handbuch der Mineral Chemie," **I**, 231.

⁴ O. Kallauner, "Thermal Dissociation of Amorphous Magnesite," *Chem. Ztg.*, **37**, 182 (1913); "Thermal Dissociation of Normal Dolomite," *Chem. Ztg.*, **37**, 1317 (1913).

lower than that of magnesite. It is not unlikely that this fact has a favorable effect in the calcination of the Austrian breunnerite.

Crystalline Magnesite.—Crystalline magnesite occurs in much larger deposits than does the compact type and hence can usually be produced more cheaply. The texture of breunnerite is much coarser than that of spathic magnesite low in iron, much of which has an even, granular, sugary texture, resembling calcite and dolomite. Magnesite can be distinguished from these minerals by its higher specific gravity and its behavior towards acids, being more difficultly soluble; it is almost insoluble in cold acids, but when powdered dissolves readily in warm HCl.

The most noteworthy deposits of crystalline magnesia are in Austria-Hungary, Quebec and Washington. It almost invariably occurs in association with dolomite, with which its origin is closely connected. It is generally held that the Austro-Hungarian deposits are limestone replacements, formed by the action of ascending aqueous solutions carrying magnesium carbonate and high in iron compounds. These solutions penetrated the limestone beds, forming dolomite and magnesite through replacement of lime by magnesia.¹ A somewhat similar origin is attributed to the crystalline magnesite of Quebec,² although in this case the circulating waters were not high in iron. The Washington deposits occur in sedimentary rocks, probably of Paleozoic age, not far distant from igneous intrusives. It is believed that these magnesite deposits represent replacements of dolomite bodies, and that the intrusives were the source from which replacement was effected through the agency of circulating waters.³

There are many deposits of crystalline magnesite of the breunnerite type in Styria, Lower Austria, and Northern Hungary, of which about a dozen are large enough to be commercially workable. The Styrian and Lower Austrian deposits occur in a belt

¹ K. Redlich, "Genesis of the Pinolite Magnesite, Siderite and Ankerite of the Eastern Alps," *Mineralog. petro. Mitt.*, **26**, 499 (1912); J. Hörhager, "The Formation of Magnesite Deposits and their Association with Iron Ore Beds," *Oester. Z. Berg.-Hüttenw.*, **59**, 222 (1910).

² M. E. Wilson, "The Magnesite Deposits of the Grenville District, Quebec," *Memoir 98 of Canadian Geol. Survey*, **34** (1917).

³ Olaf P. Jenkins, "Notes on the Possible Origin of the Magnesite Near Valley, Washington," *Econ. Geol.*, **13**, 381 (1918).

southwest of Vienna, extending from the Semmering to the Tyrol; some of them are less than 100 miles from the Adriatic Sea. The most important occurrences, taken in order from east to west, are those at Semmering, (Eichberg) Veitsch, Brietenau, Trieben, Redenthein (Minstatt) and Dientin (Salzburg). The formation extends eastward beyond Vienna into Northern Hungary, where magnesite is quarried between Jolsva and Nyustya, at a distance of 360 miles from Fiume, the nearest port on the Adriatic.¹ Most of the material exported has come from Styria and Lower Austria on account of the much shorter distance to the shipping point on the coast.

The Austrian magnesite occurs in the form of huge lenticular masses in a belt of carboniferous rocks consisting mainly of metamorphosed shales, sandstones, and conglomerates. The largest and most celebrated deposit is the one at Veitsch near Mittendorf station in Styria. It was acquired by Carl Spaeter in 1880, and mining began in 1881 with small output. The lens is nearly three-quarters of a mile long and over 1000 feet in width and probably continues to a considerable depth. The magnesite is mottled, of various shades of grays and drabs, but turns brown on exposure to the air on account of oxidation of the ferrous carbonate. It is quarried in a series of terraces, 50 feet apart vertically, extending from the summit of the hill to the base of the deposit 700 to 800 feet lower.² The large blocks of stone blasted from the quarry face are broken to pieces of head size and cobbled to remove impurities such as schist, dolomite and quartz; and lumps high in impurities are reduced to fist-sized pieces for further dressing. The loss in sorting is said to amount to one-half to two-thirds of the material quarried. After separation from the waste rock, the magnesite is transported by gravity planes to the calcining plant at the foot of the hill. It is said to show the following range of composition:

| | |
|--------------------------------------|-------------|
| MgCO ₃ | 83 to 94.0% |
| CaCO ₃ | 0.5 to 4.5 |
| FeCO ₃ | 4 to 12 |
| SiO ₂ | up to 3 |
| Al ₂ O ₃ | up to 1 |
| Mn ₂ O ₃ | up to 0.5 |

¹ Thomas Crook, *op. cit.*, p. 79; Anonymous, "An Austrian Magnesite Property Developed by American Capital," *Iron Trade Rev.*, **55**, 772 (1914).

² L. C. Morganroth, "The Occurrence, Preparation and Use of Magnesite," *Trans. Am. Inst. Mining Eng.*, **50**, 890 (1914).

Although the crude magnesite shows considerable variation in the content of ferrous carbonate, the dead-burned product as marketed is very uniform in composition, on account of the care in treatment and the thoroughness of mixing.

Quebec.—In the Grenville district, Quebec, crystalline magnesite occurs in large lenticular masses in the Grenville series of metamorphic sedimentary rocks, intimately associated with serpentine and dolomite. Masses of the latter, of irregular size and shape, are scattered throughout the deposits. The magnesite is snow-white to grayish, finely crystalline, and high in lime due to dolomite inclusions. Wilson in 1917 estimated that there were in sight a little less than 700,000 tons containing under 12 per cent CaO, much of which contained no more than 7 per cent to 10 per cent CaO (equivalent to 12.5 to 18 per cent CaCO_3). The deposits were opened in a small way in 1907, but no shipments of consequence were made prior to the war. During the war magnesite was quarried by two companies, and is still being produced, though in diminished quantity. The output has been used almost wholly for the production of dead-burned grains for furnace bottoms as a substitute for Austrian magnesite; on account of the high lime content, the product is not considered very desirable for this purpose and has been largely supplanted by the purer material from Washington.

Washington.¹—The Washington magnesite deposits occur near Valley and Chewelah, on the Great Northern Railroad, about sixty miles north of Spokane. Shipments began in 1916 with an output of 715 tons of crude magnesite; in 1917, 105,175 tons were produced, and in 1918, 147,528 tons.

The mineral varies from 93 to 97.5 per cent MgCO_3 ; it is finely to coarsely crystalline and shows many variations in color from white to gray, pink, red and black, although pink and light gray are the predominant colors. It occurs as huge steeply pitching

¹ R. W. Stone, "Magnesite Deposits of Washington," *Eng. Mining J.*, 105, 665 (1918); C. D. Dolman, "Magnesite: Its Geology, Products and their Uses," *Bull.* 152; *Am. Inst. Mining Met. Eng.*, 1193 (1919); C. G. Yale and R. W. Stone, "Magnesite in 1917," *Mineral Resources of the United States*, 1917 (1918), Pt. II, p. 65.

lenses in thick dolomite beds which are overlain by quartzite, underlain by shale and slate and associated with igneous greenstone. There are six or seven known deposits in the district, and

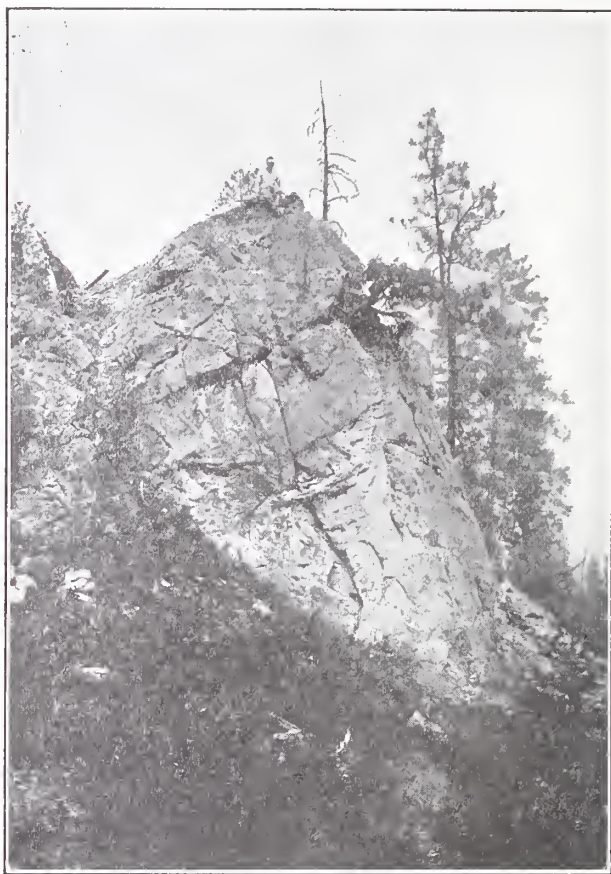


FIG. 1.—A magnesite outcrop near Chewelah, Washington

the amount available from them all has been estimated at not less than seven million tons, with a probability that more will be developed by future exploratory work. The Finch deposit of the Northwest Magnesite Company has a length of 1500 feet and a thickness of 200 feet, and it is reported that diamond drilling

has proven the existence of more than 1,000,000 tons of high-grade magnesite. The Red Marble deposit is about a quarter of a mile long and 200 to 300 feet thick. Other important deposits are the Allen, Double Eagle and Keystone.

The material shipped by the Northwest Magnesite Company, which is secured from the Finch quarry, is mined from a deep open-air pit sunk on the mountain side, such as is commonly known as a "glory-hole." The glory-hole has a horizontal floor with two chutes which connect with a level at a lower elevation; one chute is used for good magnesite, the other for waste. The magnesite, after being blasted down from the sides of the hole, is broken with sledges to pieces of one-man size. Fine material, which is high in silica, is screened out with pitchforks. The waste amounts to about 20 per cent of the total. Good rock and waste are drawn from the chutes into cars on the lower level, and the good magnesite is given a preliminary crushing before transportation to the calcining plant. This is five miles distant on the Great Northern Railroad near Chewelah.

TYPICAL ANALYSES OF WASHINGTON MAGNESITE

| | | | | |
|---|-------|-------|-------|-------|
| SiO ₂ | 1.9 | 3.3 | 4.3 | 0.6 |
| Fe ₂ O ₃ and Al ₂ O ₃ | 1.0 | 1.0 | 0.8 | 1.2 |
| CaO..... | 1.7 | 1.4 | 1.1 | 0.5 |
| MgO..... | 45.2 | 44.8 | 45.0 | 46.4 |
| CO ₂ | 49.7 | 49.3 | 49.5 | 51.0 |
| | <hr/> | <hr/> | <hr/> | <hr/> |
| | 99.5 | 99.8 | 100.7 | 99.7 |

Cryptocrystalline Magnesite

Cryptocrystalline, or amorphous magnesite occurs in serpentine in the form of irregular veins, lenses, reniform masses and stockwork. It is believed to be one of the decomposition products formed during the serpentinization of magnesian-silicate rocks, such as olivine and enstatite, and during the subsequent decomposition of the serpentine through the action of waters bearing CO₂.¹ The most important deposits are those of Greece and California; it is found also in India, near the town of Salem; in

¹ S. H. Dolbear, "The Origin and Geo-Chemistry of Magnesite," *Mining Sci. Press*, 114, 237 (1917).

the Transvaal; in Venezuela; on Santa Margarita and Cedros Islands, off the west coast of Mexico; and in many other places.

Greece.¹—The most widely known deposits of amorphous magnesite are those on the Island of Euboea, Greece. They vary considerably in size, but are larger than most deposits of this type. The bodies range from 6½ to 130 feet in thickness and up to 500 feet in length; the depth to which mining operations can be carried rarely exceeds 200 feet. The magnesium carbonate content varies from 94 per cent to 98 per cent, and the impurities are correspondingly low, although careful sorting at the mines is necessary in order to remove serpentine and other waste material. When this is not done, the silica and lime content is likely to be high.

These deposits have been worked for many years. Export began in 1870; by 1899 the annual output had risen to 35,000 tons. The amount produced in recent years, expressed in metric tons,² is as follows:

| | | | |
|-----------|---------|-----------|---------|
| 1911..... | 86,956 | 1914..... | 136,701 |
| 1912..... | 106,338 | 1915..... | 159,981 |
| 1913..... | 118,054 | 1916..... | 199,484 |

Considerable Grecian magnesite was shipped to the United States during 1915 and 1916, but shipments were suspended late in 1916, and no more was imported while the war lasted.

California.³—Amorphous magnesite occurs at many places in California, in veins and lenses which are usually small, and which show considerable variation in length and thickness. Although it has been mined in ten or twelve counties, the largest and most important deposits are those at Porterville, Tulare County, and St. Helena, Napa County. At Porterville there are many veins, averaging four to five feet in thickness; the main body at the

¹ W. Donald, *op. cit.*, p. 96; J. Hogg, "Magnesite Deposits in Euboea, Greece," *Trans. Inst. Mining Eng.*, 46, 128 (1914).

² Metric ton = 1.1023 net tons.

³ Frank L. Hess, "The Magnesite Deposits of California," *Bull.* 355, U. S. Geol. Survey (1908); Anonymous, "California Magnesite," *Iron Age*, 99, 845 (1917); W. C. Phalen, "Magnesite Industry in the United States," *Mining Sci. Press*, 119, 295 (1919); S. H. Dolbear, "Magnesite Deposits and Possibilities in California," *Mining Press*, 110, 105 (1915).

White Rock deposit, near St. Helena, is over 20 feet thick. Mining is usually done by running levels, stoping out the magnesite, and back-filling. Prior to 1914 about 10,000 tons were being produced annually; in 1917 this had grown to 211,773 net tons. In the following year the production dropped to 84,077 tons and in 1919 to about 60,000 tons.

TYPICAL ANALYSES OF CALIFORNIA CRUDE MAGNESITE

| | | | | | |
|---|--------|--------|-------|-------|--------|
| SiO ₂ | 3.25 | 5.18 | 1.10 | 3.86 | 1.55 |
| Fe ₂ O ₃ and Al ₂ O ₃ | 2.20 | 1.10 | 0.40 | 0.80 | 0.45 |
| CaO..... | 1.25 | 3.34 | Trace | 2.04 | 1.38 |
| MgO..... | 43.87 | 41.92 | 46.47 | 43.47 | 45.68 |
| CO ₂ | 49.53 | 48.78 | 51.20 | 49.48 | 50.97 |
| | <hr/> | <hr/> | <hr/> | <hr/> | <hr/> |
| | 100.10 | 100.32 | 99.24 | 99.65 | 100.03 |

PART III. MANUFACTURE OF MAGNESITE PRODUCTS

Nomenclature

The names applied to the different magnesite products are somewhat confusing, as they are not infrequently used interchangeably to designate products dissimilar in character. The definitions given below are believed to represent common usage.

MAGNESITE: (1) The mineral MgCO₃, the crude material of the magnesite industry; (2) a term applied to various products manufactured from the mineral MgCO₃, such as "dead-burned" and "plastic" magnesite, magnesite brick and so forth.

PLASTIC MAGNESITE OR CAUSTIC BURNED MAGNESIA: The product which results from calcining crude magnesite at a comparatively low temperature, and which contains about 2 per cent to 5 per cent CO₂; called also calcined magnesite.

CALCINED MAGNESITE: (1) Magnesite which has been calcined at any temperature, including both caustic and dead-burned; (2) an intermediate product between caustic and dead-burned magnesite, *i. e.*, magnesite which has been calcined but not sintered, and in which the CO₂ content is below 2 per cent, usually about 1 per cent.

DEAD BURNED MAGNESITE OR DEAD BURNED MAGNESIA: A sintered product obtained by calcining magnesite at a high temperature; it usually contains less than 0.5 per cent CO₂ and almost invariably contains 4.5 to 8 per cent Fe₂O₃, either naturally or by additions of iron ore during the treatment.

ELECTRICALLY SHRUNK MAGNESIA: Magnesite calcined in the electric furnace to effect complete shrinkage; usually of a high degree of purity.

MAGNESIA OR MAGNESITE BRICK: Brick consisting essentially of MgO , generally containing 4.5 to 8 per cent Fe_2O_3 . It has been suggested that brick with this amount of iron be called "magnesite brick," and those nearly free from iron "magnesia brick," but the latter term is more frequently applied to both.

MAGNESIA: (1) The pure oxide of magnesium; (2) a term applied synonymously with "magnesite" to brick, dead-burned material, and so forth; (3) to certain magnesite products low in impurities and high in MgO , as magnesia crucibles, electrically shrunk or fused magnesia, and so forth, and (4) also applied to precipitated or basic carbonate of magnesia.

BASIC CARBONATE OF MAGNESIA: A light powdery material prepared either by boiling a solution of acid magnesium carbonate, or by double decomposition of a soluble magnesium salt and a soluble carbonate. The composition of the commercial product varies somewhat, but is generally given as $3\text{MgCO}_3 \cdot \text{Mg}(\text{OH})_2 + 3\text{H}_2\text{O}$, the same as that of hydromagnesite.

Calcination of Magnesite

The first step in the preparation of magnesite products is calcination of the crude mineral, in order to drive off more or less completely the carbon dioxide with which the magnesia is chemically combined. This treatment causes a loss of about 50 per cent in weight, a considerable decrease in volume, and marked changes in physical properties. The character of the resultant product is dependent upon the time and temperature of calcination, and the amount and composition of impurities present. Caustic burned magnesia is produced by calcining the crude material at a temperature of 700° to 1000°C . It contains from about 2 to 5 per cent CO_2 , and on account of its setting properties when mixed with a solution of magnesium chloride, is used as a flooring material and for the production of artificial stone and so forth. For this purpose the amorphous type of magnesite is preferred to the crystalline, because of its white color and lower content of impurities.

Dead-burned magnesite¹ results from calcining either the crude or the lightly calcined material at a temperature that will not merely drive off nearly all the CO_2 , but will also cause sintering of the particles. During this process the pieces shrink consid-

¹ J. Hörhager, "On Magnesite," *Stahl u. Eisen*, **31**, 958 (1911); H. O. Hoffman, "General Metallurgy," published by McGraw-Hill Book Co., 1913, p. 370.

erably and become hard, dense, and inert to atmospheric moisture and CO_2 . The temperature at which this occurs depends on the texture and composition of the crude magnesite. One high in iron oxide, such as the Styrian, will shrink and frit together at 1450° to 1500°C ; while a temperature of 1600° to 1700°C or higher is required for one low in iron oxide and other impurities. For this reason a small percentage of iron oxide is considered necessary for the production of dead-burned magnesite satisfactory for most refractory purposes, which will not be subject to further shrinkage at furnace temperatures and which will sinter together to form a well-bonded furnace hearth at working temperatures. From 4.5 per cent to 8 per cent Fe_2O_3 in the dead-burned grains is regarded as the most desirable amount. If the crude material used is too low in iron, the oxide may be added in the form of iron ore; the ore and the magnesite should be finely ground and intimately mixed before calcination. Prior to the war the Austrian crystalline magnesite was used exclusively for the production of dead-burned magnesite, since it naturally contains the amount of iron oxide considered to be most satisfactory.

The fact that amorphous magnesite is preferred for the production of caustic magnesia, and the crystalline variety for that of dead-burned magnesite, has often led to the conclusion that amorphous magnesite only can be used in the manufacture of caustic burned magnesia, and the crystalline magnesite only in the preparation of dead-burned magnesite. As a matter of fact, caustic burned magnesia of excellent grade (color excepted) has been produced from crystalline magnesite;¹ and dead-burned magnesite of high quality has been produced in this country since 1914 from magnesite of the amorphous type.

When calcined in the lump form, amorphous magnesite develops a columnar structure; the Austrian crystalline magnesite retains its cleavage form and shows rhombohedral fragments even when calcined. The coarseness of texture of many crystalline magnesites is an advantage, as dolomitic impurities are likely to be less intimately admixed when the texture is coarse than when it is

¹ R. D. Pike, Northwest Magnesite Company, private communication.

fine, and their removal is, therefore, easier. The effect of the crystal cleavages in giving the kiln gases access to the interior of all lumps is to decrease fuel consumption, and may be partly responsible for the fact that crystalline magnesite is more easily calcined than is the amorphous variety.

By calcination in the electric furnace above 1700°C , pure magnesite may be shrunk to a hard, flinty mass, with a specific gravity of about 3.65, which shows no additional shrinkage on further heating.¹

Austria.²—In Austria magnesite is dead-burned in shaft kilns of the bottle type and in rotary kilns. The former are fired with producer gas and produce 15 to 24 tons of sintered product in 24 hours; the rotary kilns, fired with powdered coal, produce 50 to 60 tons per day. Less fuel is required when the ferrous carbonate content of the magnesite is fairly high than when it is low. Good flaming brown coal with a calorific value of 6000 calories is used, and the consumption is said to vary from 600 to 800 pounds per ton of dead-burned material. The abundance and accessibility of the brown coal have been important factors in the development of the Austrian magnesite industry.

After calcination, the magnesite must again be sorted to remove impurities not discarded at the quarries. Separation from impurities is facilitated by the dark color and magnetic properties acquired in burning, both of which are imparted by the iron present. The sintered material is crushed and sized mechanically, and the coarser particles are usually hand picked to sort out under-burned grains, as well as talc, dolomite and quartz. Much of the lime present falls readily to dust, and is removed by the first screening. Magnetic separation is practiced at some plants.

The Austrian magnesite formerly imported into the United States had approximately the following analysis:

¹ R. C. Gosrow, "Refractory Magnesia," *Met. Chem. Eng.*, **17**, 415 (1917).

² L. C. Morganroth, "Occurrence, Preparation and Use of Magnesite," *Trans. Am. Inst. Mining Eng.*, **50**, 890 (1914); Anonymous, "Works of the Austro-American Magnesite Co.," *Iron Trade Rev.*, **48**, 111 (1911); Anonymous, "An Austrian Magnesite Property Developed by American Capital," *Ibid.*, **55**, 772 (1914).

| | Range | Average |
|--------------------------------------|-----------|---------|
| MgO..... | 83.0-89.0 | 85.6 |
| CaO..... | 1.5- 4.0 | 2.9 |
| SiO ₂ | 1.0- 4.0 | 2.8 |
| Al ₂ O ₃ | 0.2- 1.5 | 0.6 |
| Fe ₂ O ₃ | 4.0- 8.5 | 7.1 |
| Mn ₂ O ₃ | 0.5- 0.8 | 0.6 |

Greece.—Large bottle-shaped kilns, fired with producer gas, are used on the Island of Euboea in calcining magnesite for export. Prior to the war over half the magnesite produced was calcined to the caustic condition and shipped to Germany, where it found application principally as a building material.

Canada.—At Hull, Quebec, 60-foot rotary kilns, with powdered coal as fuel, were used during the war for calcining magnesite from the Grenville district. It is said that after crushing, the crude mineral was mixed with several per cent of magnetic iron ore, ground in a ball mill, and burned in the rotary kilns, forming sintered nodules of a dark brown color. The analysis of the grains produced is approximately as follows:

| | |
|--------------------------------------|------|
| MgO..... | 67.5 |
| CaO..... | 17.7 |
| SiO ₂ | 5.5 |
| Al ₂ O ₃ | 2.0 |
| Fe ₂ O ₃ | 7.1 |

California.¹—In California magnesite is calcined in bottle-shaped and vertical shaft kilns and in rotary kilns. The material charged into shaft kilns must be in the lump form as the draft would be choked by fines. For feeding into rotary kilns the lumps are first crushed, in some plants to 1½ inch diameter, and in others to ½ inch diameter or smaller. The latter practice is the more recent, and is considered the more satisfactory.

A vertical shaft kiln of the customary size produces about 7 to 10 tons of calcined magnesite in 24 hours, a bottle-shaped kiln 15 to 20 tons, and a 125-foot rotary, 7½ × 7 feet in diameter 60 to 75 tons. The total calcining capacity of all the plants in California is estimated at 10,000 to 12,000 tons per month. The greater portion of their output is not dead-burned and is, there-

¹ W. C. Phalen, "The Magnesite Industry in the United States," *Mining Sci. Press*, 119, 295 (1919).

fore used otherwise than as a refractory material. Distillate and crude oil are the usual fuels, but coke is used in some plants. It is generally estimated that in the rotary kilns 1 to $1\frac{1}{3}$ barrels of crude oil are consumed per ton of magnesite when the latter is burned to 0.5 per cent ignition loss, but not sintered with iron. At the White Rock Mine in Napa County, Alabama coke is charged in layers with the magnesite in vertical kilns, and it is stated that 320 pounds of coke are required per ton of dead-burned magnesite produced.

On account of the low content of iron of nearly all Californian magnesite, very little can be used for the manufacture of refractory magnesite without the addition of iron. In two producing mines of the state, however, the calcined product naturally contains an average of 4.5 per cent iron oxide and alumina. Such material turns reddish brown in burning; magnesite free from iron remains perfectly white, and for that reason is preferred as a plastic flooring material.

Washington.—The largest producer in the Washington field is the Northwest Magnesite Company, which has five $7\frac{1}{2} \times 125$ -foot rotary kilns at Chewelah, with a total rated capacity of 9,000 tons of dead-burned magnesite per month. The lumps of magnesite coming from the mine are finely ground and mixed with $2\frac{1}{4}$ per cent of iron ore before feeding into the kilns. Pulverized coal with about 13,000 B.T.U.'s per pound is used as fuel, and the consumption is about 800 lbs. of coal per ton of dead-burned magnesite produced.¹ The heat of the kilns causes the finely pulverized material to sinter together, forming dense, hard nodules. The dead-burned product on coming from the kilns is passed through a rotary cooler, then crushed by rolls to the proper size. The average analysis of the dead-burned magnesite produced by the Northwest Magnesite Company is given below:

AVERAGE ANALYSIS OF NORTHWEST MAGNESITE COMPANY PRODUCT,
JULY 1918 TO NOVEMBER 1919²

| | |
|---|-------|
| MgO..... | 83.04 |
| CaO..... | 3.11 |
| Mn ₂ O ₃ | Trace |
| Fe ₂ O ₃ and Al ₂ O ₃ | 7.02 |
| SiO ₂ | 6.78 |

¹ R. D. Pike, Northwest Magnesite Co., private communication.

² Advertising booklet of Northwest Magnesite Co. (1919).

Magnesia Crucibles

Small magnesia crucibles are made for various purposes; for muffle use they have been prepared by machining magnesite brick.¹ For preparing ferro-alloys, O. P. Watts² has made magnesia linings for graphite laboratory crucibles, to prevent contamination of the charge by carbon from the graphite. Calcined magnesia, moistened with water, was tamped around a wooden core in a graphite crucible. After removal of the core, the lining was dried in an oven and burned in a carbon resistance furnace, at a temperature above that to be used in forming the alloys. Iron oxide, when present in the magnesia, was harmful, for it distilled out in the burning, and corroded both the crucible and the magnesia lining. Average linings 6 inches high and $3\frac{1}{8}$ inches in diameter shrunk 17 per cent in length and 12 per cent in diameter during the burning. After burning they could be readily removed, were hard and stone-like, and showed a crystalline fracture. However, they could not be handled at a white heat, and it was found necessary to replace them in the graphite crucible for use at high temperatures. Attempts to increase the strength at high temperatures by the addition of other refractory materials to the magnesia were not successful. The maximum temperature to which the crucibles could be used was fixed by the reduction of the magnesia by the graphite.

Yensen³ has made magnesia crucibles for laboratory purposes from calcined magnesia fused in an electric arc furnace. The fused magnesia was crushed to pass a 40-mesh screen, mixed with 5 per cent hydrated magnesia, molded into crucibles under heavy pressure in a steel mold, dried and heated to 1800° C in an electric furnace. The crucibles were said to be uniform and strong, with little shrinkage, and to show no sign of softening at 1800° C. The magnesia used contained 5 per cent impurities. Fitzgerald⁴ had previously found that a crucible made from Grecian

¹ Donald M. Liddell, "Magnesite Crucibles," *Eng. Mining J.*, **96**, 503 (1913).

² O. P. Watts, "Making of Magnesia Crucibles," *Mining Sci.*, **66**, 413 (1912).

³ T. D. Yensen, "Magnesia Ware," *J. Am. Ceram. Soc.*, **1**, 730 (1918).

⁴ F. A. J. Fitzgerald, "Refractories," *Met. Chem. Eng.*, **10**, 129 (1912).

magnesite of a high degree of purity and said to be "highly calcined" cracked so badly as to be useless when heated gradually to 1500°C and cooled slowly; while one of material which had been electrically calcined developed only a few small cracks and was otherwise in good condition after fairly rapid heating to above cone 35 (*i. e.*, above 1755°C), followed by slow cooling.

Manufacture of Magnesite Brick¹

Magnesite brick is commonly made from dead-burned magnesite containing 4.5 to 8 per cent Fe_2O_3 , although for special purposes a few are manufactured from magnesite low in iron such as the Grecian. It is essential, in order to minimize burning shrinkage, that the material used be thoroughly dead-burned to a high specific gravity.

The use of bonding material is not customary in American practice. Caustic magnesite was at one time generally employed for this purpose, but it is not now favored for, while it is an advantage in molding, it has the disadvantage of high burning shrinkage. In Europe serpentine has been used to bond the amorphous magnesite of Greece; clay up to 15 per cent has likewise been tried, but it decreased the refractoriness to an excessive degree. Brick made with a binder of silicate of soda proved mechanically weak at high temperatures and readily cracked. Temporary bonds, such as tar, molasses, and dextrine are more or less employed in Europe to hold the particles together before burning.

In the early nineties bricks were being made at Brieg in Silesia from dead-burned amorphous magnesite bonded with caustic magnesite to which magnesium chloride had been added. They were molded in a hydraulic press at about 1500 pounds pressure per square inch.² In Europe, up to a few years before the war,³

¹ E. T. Montgomery, "Refractory Brick," *Brick and Clay Record*, **44**, 1144 (1914); A. B. Searles, "Refractory Materials," Chas. Griffin & Co., 242 (1917).

² Thomas Crook, *op. cit.*, p. 70.

³ C. Schimm, "Burning of Magnesite and Magnesite Brick," *Stahl u. Eisen*, **26**, 303 (1906); J. Hörhager, "On Magnesite," *Stahl u. Eisen*, **31**, 955 (1911); Dr. Kern, "Magnesite and Its Technical Utilization," *Glückauf*, **48**, 271 (1912).

the dead-burned magnesite, after crushing and sorting, was ground in edge-runner or ball mills to $1\frac{1}{2}$ millimeters (about $\frac{1}{16}$ inch). The specific gravity was often obtained to give an indication of the amount of shrinkage likely to occur, and to permit of definite volume weight to be made from material of different batches. Ten per cent of caustic magnesite at times was added as a bond, but was more frequently omitted. The ground mass was moistened with 4 to 5 per cent of water, sometimes though not usually, with the addition of dextrine or similar binder, and mixed in a trough mixer or pan mill. After mixing, it was in some cases allowed to stand from 2 days to 3 weeks before pressing. It was molded in a hydraulic press at 3500 to 7000 pounds per square inch, depending upon the character of the magnesite used, and its difficulty of sintering. Material which could be easily sintered was given the lower pressure. The green bricks were dried slowly, sometimes in dryers heated by waste steam, at others in well-ventilated sheds heated only in the winter months. They were commonly, but not always, burned in the same kiln with silica brick, being set in the upper part of the kiln on top of the latter, and surrounded by silica brick for protection from the flames. The maximum burning temperature was maintained 24 hours; it was usually about cone 18, although some German manufacturers heated to cone 26. It has been stated that brick burned to cone 30 to 34 shrink to such an extent that they can be used in furnace arches.

In the United States, the dead-burned magnesite, after having been finely ground, is thoroughly mixed in a wet pan with a small amount of water. The bricks are molded, as a rule, in a power press. The green brick, placed on rack cars, are dried in tunnel driers; they are extremely fragile before drying, but are usually hard and tough when dry. They must be set in the kilns with care, as they are easily deformed during burning by a slight load. For this reason they are boxed in with silica brick in such a way that there is practically no load upon them. Burning takes place in rectangular down-draft kilns; cooling is done slowly in order to avoid cracking of the brick. The burning shrinkage amounts to about $\frac{3}{32}$ to $\frac{1}{8}$ inch per foot.

An ingenious form of magnesite brick, said to be especially

adapted for service in open-hearth and electric furnaces, has been put on the market within the last few years under the trade name of "metalkase brick."¹ These bricks consist of round or square soft steel containers, open at the ends and of a convenient size for handling and laying, packed with dead-burned magnesite.

PART IV. PROPERTIES OF CAUSTIC, DEAD-BURNED, AND FUSED MAGNESIA

Color, Texture, etc.—The caustic burned magnesia sold for various purposes is usually white, the color preferred by most users; it is sometimes buff or reddish brown, depending upon the amount and character of the impurities present. It is easily pulverized, and lumps fall readily to powder upon exposure to the air.

Dead-burned magnesite is red, reddish brown, chocolate brown, black, or of intermediate color. Iron oxide in the absence of manganese imparts a reddish color, while the combined coloring effect of iron oxide and small quantities of manganese produces rich chocolate brown to black. Dead-burned magnesite is hard and dense; it is marketed in the form of nodules or grains varying from $\frac{5}{8}$ inch diameter to extremely fine particles.

Fused magnesia prepared in the electric furnace is generally low in impurities and white in color. It is very hard (hardness 5 to 6) and resembles glazed porcelain. When cooled rapidly the crystals are minute and compact; if cooled slowly they are fairly large and in well-defined layers.²

The latent heat of fusion of MgO is 700 (± 15 per cent) calories per gram.³ Its fusion point is 2800°C ,⁴ although it becomes somewhat plastic and mechanically weak at temperatures far below this. At 1000°C below its melting point it will bond together to a dense mass which is hard and strong when cold.

¹ W. F. Rochow, "The Selection of Refractories for Industrial Furnaces," *J. Ind. Eng. Chem.*, **11**, 1146 (1919).

² Goodwin and Mailey, "Properties of Fused Magnesium Oxide," *Trans. Am. Electrochem. Soc.*, **9**, 89 (1906).

³ E. W. Washburn, "Latent Heats of Fusion of Lime and Magnesia," *Trans. Am. Ceram. Soc.*, **19**, 195 (1917).

⁴ C. W. Kanolt, "The Melting Points of Some Refractory Oxides," *J. Wash. Acad. Sci.*, **3**, 315 (1913).

This fact suggests that MgO has an appreciable vapor pressure at temperatures much lower than the melting point. Commercial dead-burned magnesite, containing 12 per cent impurities, does not melt at 2000°C .¹ W. R. Mott² has given the boiling point of magnesia as 3600°C , lime 3400°C , and alumina 3800°C .

Specific Heat.—The mean specific heat of pure magnesia at various temperatures is as follows:

| Degrees centigrade | | | Mean specific heat between t_1 and t_2 | Observer |
|--------------------|-------|----------|--|----------------------|
| t_1 | t_2 | Mean t | | |
| -191 | -80 | -135 | 0.1006 | Russell ³ |
| -79 | 0 | -39 | 0.1933 | Russell |
| 22 | 99 | 61 | 0.2340 | Magnus ⁴ |
| 15 | 268 | 142 | 0.2520 | Magnus |
| 15 | 559 | 287 | 0.2670 | Magnus |
| 16 | 765 | 390 | 0.2762 | Magnus |

Microscopic Structure, Specific Gravity and Shrinkage.—

In the calcination of magnesite, either of the crystalline or the dense variety, the product first resulting from the dissociation of MgCO_3 consists of very fine grained amorphous magnesia,⁵ with a specific gravity of about 3.2,⁶ called α -magnesia by Mellor. This, if heated at a sufficiently high temperature, is gradually transformed into the mineral periclase, Mellor's β -magnesia, the specific gravity of which is 3.674. Caustic burned magnesia is composed essentially of amorphous magnesia, while the dead-burned material is largely periclase. The theoretical volume shrinkage accompanying the transformation is 13 per cent; the total shrinkage is actually greater than this, on account of crystal-growth and change in porosity.

¹ Raymond M. Howe, private notes.

² Meeting of Am. Electrochem. Soc., Oct. 2, 1918.

³ A. S. Russell, "Measurements of Specific Heats at Low Temperatures," *Phys. Ztg.*, **13**, 59 (1912).

⁴ A. Magnus, "Measurements of the Specific Heats of Solids at High Temperatures," *Ibid.*, **14**, 5 (1913).

⁵ J. W. Mellor, "Spalling of Magnesite Bricks," *Trans. Ceram. Soc. (Eng.)*, **16**, 85 (1916-17).

⁶ J. W. Mellor (*op. cit.*) gives this figure; W. Donald gives 3.01. (W. Donald, "Magnesite and Magnesite Brick," *Trans. Ceram. Soc. (Eng.)*, **17**, Pt. II, 504, (1917-18).

Not only because of the chemical activity of amorphous magnesite, but also on account of the shrinkage, material to be used for refractory purposes should show a high degree of conversion to periclase. The completeness to which the transformation has taken place may be estimated from specific gravity determinations. The higher the specific gravity, the less will be any additional shrinkage on reheating to high temperatures.

Commercial caustic magnesite has a specific gravity from 3.20 to 3.30; higher values indicate overburning. The density of dead-burned magnesite is slightly less or greater than 3.50.

Moissan¹ found fused magnesite to have a specific gravity of 3.577 to 3.654. The latter figure was obtained on a 50 gram specimen which had fused into a single piece in the electric furnace. Fitzgerald and Bennie² report a specific gravity of 3.572 for fused magnesite containing about 6 per cent impurities.

Chemical Composition.—The chemical analyses of caustic and electrically fused magnesite will not be given here; they are usually low in impurities. The effect of the fluxing impurities contained in dead-burned magnesite will be discussed from a theoretical standpoint in the notes on microscopic examination, and the comments here made will, therefore, pertain merely to industrial practice.

Commercial dead-burned magnesite and brick made therefrom have the following average analyses:

| Oxide | Austrian | Washington |
|--------------------------------------|----------|------------|
| MgO..... | 85.6 | 83.1 |
| CaO..... | 2.9 | 3.1 |
| SiO ₂ | 2.8 | 6.8 |
| Al ₂ O ₃ | .6 | 2.0 |
| Fe ₂ O ₃ | 7.1 | 5.0 |
| Mn ₃ O ₄ | .6 | Trace |

With the proportion of Fe₂O₃ shown in the above analyses, dead-burned magnesite has a long range of vitrification and develops good bonding properties at 1500°–1600° C, so that objects made from it and burned at that temperature are mechanically

¹ H. Moissan, "Determinations of the Density of MgO," *Compt. rend.*, 118, 506 (1894).

² Fitzgerald and Bennie, *Trans. Am. Electrochem. Soc.*, 9, 101 (1906).

strong. The proper proportion of iron is somewhat dependent upon the silica content as less is required when the silica content is high than when it is low. Since silica exerts considerable fluxing action when present in excessive amounts, particularly when the lime content is high, its percentage should preferably be less than 8 per cent of the total. It is generally held that CaO in excess of 5 per cent is objectionable, on account of its tendency to slake at ordinary temperatures, and to combine with other elements at high temperatures. CO₂ should be low, preferably under 0.5 per cent.

Crushing Strength of Magnesia-Silica Mixtures at High Temperatures.¹—The effect of varying the proportion of silica, upon the hot crushing strength of cylinders made of MgO-SiO₂ mixtures has been studied by Kowalke and Hougen. Pure magnesia was calcined at about 1500° C., ground to 40 mesh, mixed with varying amounts of 40-mesh quartz, moistened with 10 per cent water, molded into cylinders at 1500 pounds per square inch, dried and baked in a carbon resistance furnace to about 2100° C. These cylinders were subjected to a constant load of 66.5 pounds per square inch and heated at a uniform rate until failure had occurred. The pure magnesia cylinders failed slowly and gradually; the MgO-SiO₂ mixtures always failed abruptly. A maximum hot crushing strength was developed in mixtures containing 7½ per cent SiO₂, which failed at a temperature 190° C higher than pure magnesia. The results were as follows:

| Silica content, per cent | Average temperature of failure |
|--------------------------|--------------------------------|
| 0..... | 1680° C |
| 3..... | 1800° C |
| 6..... | 1850° C |
| 7..... | 1860° C |
| 7½..... | 1870° C |
| 8..... | 1852° C |
| 12..... | 1838° C |

Electrical Resistivity.—Northrup² gives the following figures for the electrical resistivity of electrically shrunk magnesia, to which 10 per cent pure MgCO₃ had been added for bonding:

¹ Kowalke and Hougen, "Crushing Strength of Magnesia-Silica Mixtures at High Temperatures," *Trans. Am. Electrochem. Soc.*, **33**, 215 (1918).

² E. F. Northrup, *Ibid.*, **27**, 233 (1913).

| Temperature | Resistivity in ohms per cm. cube |
|-------------|-------------------------------------|
| 1060° C | 420,000 |
| 1100° | 320,000 |
| 1170° | 62,000 |
| 1230° | 24,000 |
| 1352° | 510 |
| 1386° | 415 |

According to Goodwin and Mailey¹ fused magnesia has a higher electrical resistivity than porcelain below 1100° C, but lower above that temperature. Brace² found that, as compared with electrical porcelain, calcined magnesite has a higher electrical resistivity at all temperatures from 439° to 990° C; its ratio of initial to final resistivity is higher, and its resistivity comes to a steady value more quickly.

Thermal Expansion.—The coefficient of expansion of fused magnesia³ is not greatly different from that of platinum, being 1.14×10^{-5} at 120° C and 1.278×10^{-5} at 270° C, compared with 0.904×10^{-5} and 0.923×10^{-5} for platinum at the same temperatures. On account of the low expansion, objects made of fused magnesia will not crack with fairly rapid changes of temperature.

Hydration and Slaking.—At ordinary temperatures caustic burned magnesia forms a hydrate which is slightly plastic and can be molded, and rapidly takes up H₂O and CO₂ from the air. Since the commercial value is largely dependent upon its property of combining with water, carbon dioxide, magnesium chloride and certain other compounds, its degree of chemical activity is of considerable importance.

Gosrow⁴ has studied the rate of hydration of caustic calcined amorphous magnesite, by exposing one-quarter inch lumps to the action of moist air, and determining the increase in weight at definite intervals. The following results were obtained:

¹ Goodwin and Mailey, "Properties of Fused Magnesium Oxide," *Trans. Am. Electrochem. Soc.*, **9**, 89 (1906).

² P. H. Brace, "Electrical Resistivity of Porcelain and Magnesia at High Temperatures," *Ibid.*, **33**, 205 (1912).

³ Goodwin and Mailey, *op. cit.*

⁴ R. C. Gosrow, "Refractory Magnesia," *Met. Chem. Eng.*, **17**, 415 (1917).

| Analysis of material used | | Time of exposure to moist air, hrs. | Increase in weight, per cent |
|-------------------------------------|-------|--|------------------------------------|
| MgO..... | 94.70 | 30 | 2.50 |
| CaO..... | 0.10 | 44 | 3.25 |
| R ₂ O ₃ | 1.90 | 76 | 3.70 |
| Insoluble..... | 0.85 | 100 | 4.60 |
| Ignition loss..... | 2.20 | 125 | 5.25 |
| <hr/> | | | |
| 99.75 | | 150 | 5.60 |
| | | 172 | 6.00 |

Interesting figures regarding the influence of the temperature of calcination on the rate of hydration of light-burned magnesia are given by Campbell.¹ The material which he used was obtained by calcining magnesite of the following analysis on the basis of zero ignition loss:

| | |
|---|-------|
| MgO..... | 90.78 |
| CaO..... | 3.96 |
| SiO ₂ | 2.53 |
| Al ₂ O ₃ and Fe ₂ O ₃ | 2.70 |

For complete hydration this material required 44.59 per cent of its own weight of water.

In these tests the samples of magnesium oxide were kept barely covered with water. Those burned at 600°, 700° or 800° C were completely hydrated within three days. Between 1000° and 1100° C a change in the condition of the magnesium oxide occurs, which brings about a marked decrease in the rate of hydration. This effect is more marked as the temperature of calcining is increased. All samples calcined at not over 1100° C were completely hydrated in three months, while in the case of those heated to over 1200° C hydration was not complete after six years. The temperatures of calcining and percentages of complete hydration are given in the table below:

| Temperature of calcining | Per cent—Complete hydration, years | | |
|-----------------------------|------------------------------------|-------|------|
| | 1 | 3 | 6 |
| 1200° C..... | 91.8 | 100.0 | .. |
| 1300° C..... | 64.0 | 76.2 | 83.5 |
| 1400° C..... | 62.0 | 75.3 | 81.0 |
| 1450° C..... | 51.2 | 61.7 | 70.3 |

¹ E. DeMille Campbell, "The Influence of the Temperature of Burning on the Rate of Hydration of Magnesium Oxide," *J. Ind. Eng. Chem.*, **1**, 665 (1909); **10**, 595 (1918).

Dead-burned magnesite has no plasticity; it absorbs neither moisture nor CO_2 from the air to any appreciable extent, but forms a hydrate and slakes rapidly to an almost impalpable powder when acted on by steam.¹ The resistance to slaking of commercial dead-burned magnesite, treated dolomites and burned dolomite has been studied at the Mellon Institute.² The increase in ignition loss of these materials, when moistened daily and exposed to the atmosphere at room temperature, is given in the following table and shown graphically in sketch 2. The analyses are given on the basis of zero ignition loss, although in each case there was a certain loss at the beginning of the test.

| Material | A Wash- ington magne- site | B Can- adian magne- site | C Treated dolo- mite 1 | D Treated dolo- mite 2 | E Burned dolo- mite 1 | F Burned dolo- mite 2 |
|---|--|--------------------------------------|------------------------------------|------------------------------------|-----------------------------------|-----------------------------------|
| Silica..... | 7.40 | 4.57 | 11.52 | 9.94 | 6.93 | 2.40 |
| Alumina..... | 2.34 | 2.08 | 3.93 | 1.88 | 4.03 | 1.00 |
| Ferric oxide..... | 4.83 | 7.89 | 4.43 | 4.58 | 1.73 | 1.22 |
| Lime..... | 3.13 | 18.96 | 48.15 | 49.19 | 51.64 | 56.61 |
| Magnesia..... | 81.93 | 66.66 | 32.26 | 35.18 | 35.75 | 38.69 |
| Total..... | 99.63 | 100.16 | 100.29 | 100.77 | 100.08 | 99.92 |
| Loss on ignition at beginning of test, per cent..... | .02 | .20 | .08 | .95 | 3.93 | 14.04 |
| Ignition loss after 5 days..... | .48 | .69 | 1.20 | 5.67 | 18.45 | 25.52 |
| Ignition loss after 10 days..... | .96 | 1.52 | 1.62 | 8.35 | 20.00 | 26.30 |
| Ignition loss after 15 days..... | 1.24 | 1.94 | 2.39 | 10.10 | 23.30 | 33.00 |
| Ignition loss after 20 days..... | 1.36 | 1.92 | 3.01 | 10.92 | 23.66 | 29.70 |
| Ignition loss after 25 days..... | 2.09 | 2.65 | 6.30 | 12.00 | 24.33 | 25.99 |
| Ignition loss after 30 days..... | 2.54 | 3.25 | 4.63 | 14.99 | 24.67 | 30.81 |

It will be observed that in the case of both magnesite and dolomite the rate of slaking increases with the lime content, and that for the dolomites the rate increases as the sums of the iron oxide, silica and alumina contents decrease. The presence of these impurities, by facilitating sintering during the burning

¹ R. H. Youngman, "The Effect of Steam upon Magnesite Brick and Calcined Magnesite," *J. Ind. Eng. Chem.*, **6**, 1037 (1914); *Met. Chem. Eng.*, **12**, 620 (1914).

² McDowell and Howe, "Basic Refractories for the Open Hearth," *Trans. Am. Inst. Mining Eng.*, **55**, 291 (1919).

period, reduces, but does not overcome, the inherent tendency of lime to slake.

Fused magnesia is very slightly affected by CO_2 and H_2O at ordinary temperatures. A specimen containing 0.04 per cent CO_2 over which moist CO_2 gas was passed for 50 hours, contained only 0.42 per cent CO_2 at the end of the test.¹ Fitzgerald² describes another experiment in which ground "ordinary calcined" magnesite and "electrically calcined" magnesite were exposed to a current of moist CO_2 for 44 hours. At the end of that time the former showed 31.30 per cent increase in weight; the latter showed no increase.

Action of Carbon on Magnesia at High Temperatures.³—Various observers have noted that when magnesia and carbon are in contact at high temperatures, such as those of the electric furnace, the materials seem to shrink, the magnesia becomes deeply pitted if originally a smooth piece, and a black soot-like deposit appears on the interior walls of the cooler part of the furnace. This has been shown to be an intimate mixture of magnesia and carbon rather than a carbide. Magnesia is attacked even more severely by the carbides of iron, nickel and chromium, and by siloxicon and carborundum, than by carbon.

The generally accepted view is that the reaction is a reduction of the magnesia by the carbon according to the formula



This action is reversible, being controlled principally by the temperature; the vapors of Mg and CO, formed in the hotter part of the furnace, are reduced to a mixture of solid MgO and C in the cooler parts.

The various observers are not in accord as to the temperature

¹ Fitzgerald and Bennie, *Trans. Am. Electrochem. Soc.*, **9**, 103 (1906).

² F. A. J. Fitzgerald, "Refractories," *Met. Chem. Eng.*, **10**, 129 (1912).

³ O. P. Watts, "The Action of Carbon on Magnesia at High Temperatures," *Trans. Am. Electrochem. Soc.*, **11**, 279 (1907); Goodwin and Mailey, "Physical Properties of Fused Magnesia," *Ibid.*, **9**, 89 (1906); R. E. Slade, "Reduction of Magnesia by Carbon," *J. Chem. Soc.*, **93**, 327 (1908); P. Libeau, "Reduction of Magnesia by Carbon," *Compt. rend.*, **144**, 799 (1907).

at which this action begins. Northrup¹ observed a slight reaction between magnesia and graphite at 1450° C; Slade reports that the reaction with Acheson graphite begins at 1700° C, Kowalke and Grenfell² find that it begins slowly at 1950° C and becomes violent above 2030° C.

Magnesia cylinders containing 92.7 per cent MgO and 7.3 per cent SiO₂, when heated in a carbon resistance furnace and resting on a graphite block, lost weight at the following rates:³

| Maximum temperature | Per cent loss in weight | |
|---------------------|-------------------------|-------------------------------|
| 1500° C..... | 3.7 | 1 hour at maximum temperature |
| 1800° C..... | 7.4 | 1 hour at maximum temperature |
| 2000° C..... | 12.8 | 1 hour above 1950° C |
| 2200° C..... | 27.0 | 1 hour at maximum temperature |

The greater part of this loss was without doubt due to the MgO-C reaction, although direct volatilization of MgO probably affected the figures.

Action of Phosphorus and Silicon at High Temperatures upon Dead-burned Magnesite.—McDowell and Howe⁴ have studied the corrosive action of melts containing phosphorus and silicon upon basic crucibles. The crucibles were subjected, at 1350° C, to the action of molten mixtures of Fe₂O₃ + Fe₃P, and of Fe₂O₃ + FeSi, containing small percentages of P and Si. Fe₂O₃ alone was found not to corrode magnesite or dolomite at 1350° C. Therefore, any corrosive action of the melts upon the crucibles should be attributed chiefly to the action of phosphorus and silicon oxides formed by reduction of Fe₂O₃.

Analyses of the slags formed by melting these mixtures in basic crucibles revealed the fact that silica, lime, and magnesia went into solution in the melts, being taken from the walls of the crucibles; and led to the conclusion that the intensity of the

¹ E. F. Northrup, *Trans. Am. Electrochem. Soc.*, **27**, 234 (1915).

² Kowalke and Grenfell, "On the Temperature of Reaction between Acheson Graphite and Magnesite," *Ibid.*, **27**, 221 (1915).

³ Kowalke and Hougén, *op. cit.*

⁴ McDowell and Howe, "Basic Refractories for the Open Hearth," *Trans. Am. Inst. Mining Eng.*, **55**, 291 (1919); *Blast Furnace and Steel Plant*, **7**, 96 (1919).

action depended upon the amount of lime present in the materials of which the crucibles were made. Dead-burned magnesite low in lime was least effected, the dolomites were affected most easily, and a high-lime magnesite assumed an intermediate position.

TYPICAL PARTIAL ANALYSES OF SLAGS FROM CRUCIBLE TESTS, SHOWING RELATIVE PROPORTIONS OF OXIDES DISSOLVED FROM WALLS OF CRUCIBLES AT 1350° C BY TWO DIFFERENT MELTS

| Oxide | High P melt, 6.1 per cent P | | High Si melt, 5.2 per cent Si | |
|-------------------------------------|---|--|---|--|
| | Crucibles made from dead-burned magnesite containing 3 per cent CaO | Crucibles made from dead-burned magnesite containing 18 per cent CaO | Crucibles made from dead-burned magnesite containing 3 per cent CaO | Crucibles made from dead-burned magnesite containing 18 per cent CaO |
| SiO ₂ , per cent | 0.18 | 0.46 | ... | .. |
| CaO..... | .08 | .26 | Trace | 0.33 |
| MgO..... | .96 | 2.13 | 0.81 | 3.58 |
| Total..... | 1.22 | 2.85 | .81 | 3.91 |
| Ratio..... | 1.0 | 2.3 | 1.0 | 4.8 |

PART V. PROPERTIES OF MAGNESIA BRICK

Properties in General.—Magnesia brick naturally have many properties in common with dead-burned magnesite, from which they are made; data given in the preceding pages which apply to both will not be repeated. Their chief value lies in their chemically basic character and high refractoriness; their greatest disadvantages are their sensitiveness to rapid changes in temperature, and their inability to support heavy loads at high temperatures.

Ordinary commercial brick are reddish to dark brown or black; special brick made from amorphous magnesite such as the Grecian, are from cream to buff in color. Both give a clear ring when struck; they are heavier than fire-clay or silica brick and in the cold condition are harder and much stronger, but when hot are considerably weaker than silica brick. The weight of a standard 9-inch brick, 9 by 4½ by 2½ inches, varies from 9.5 to 10 pounds.

Kanolt¹ in 1912 determined the fusion point of an American

¹ C. W. Kanolt, "Melting Points of Firebrick," U. S. Bureau of Standards, *Tech. Paper* 10 (1912).

magnesite brick, undoubtedly manufactured from Austrian material. The melting point, taken as the lowest temperature at which a small piece of brick could be distinctly seen to flow, was found to be 2165°C . This value compares with 1710°C for fire-clay or silica brick, and 2050°C for chrome brick. Magnesia brick of the usual dark color, and containing several per cent of iron oxide, become light in color after a few minutes heating near the melting point because of volatilization of the iron.

Magnesia brick should be stored in a dry place and carefully protected from the action of steam, which causes them to disintegrate. While hot they should not come in contact with water or cold air, nor should they be subjected to rapid temperature changes, as under these conditions they will shatter and spall.

The chemical composition of the brick is the same as that of the dead-burned magnesite from which they are made; this has been discussed in the preceding pages. Brick low in iron oxide and high in MgO are more difficult to make than the usual commercial product, and are not so strong unless burned at an exceedingly high temperature. The analysis of a special brick of this character is as follows:

| | |
|-------------------------------|-------|
| MgO | 89.10 |
| Al_2O_3 | 1.15 |
| Fe_2O_3 | 1.38 |
| CaO | 3.30 |
| SiO_2 | 4.88 |

Specific Gravity.—The bulk specific gravity of magnesia brick is 2.60 to 2.75; the true specific gravity is 3.44 to 3.60, averaging about 3.52. A relationship seems to exist between the specific gravity and certain other properties, such as thermal conductivity, thermal expansion, chemical activity, and tendency to spall. This is to be expected, since a high specific gravity indicates a high proportion of periclase (density 3.67), many of whose properties are very different from those of the amorphous or low specific gravity form of MgO (density about 3.2). A high specific gravity indicates that the material is fully shrunk and that its chemical activity is weak as compared with that of amorphous magnesia.

Mellor¹ attributes the tendency of magnesia brick to crack and spall at high temperatures largely to the shrinkage accompanying the transformation of amorphous magnesia to periclase. However, there should be little, if any, spalling from this cause with bricks manufactured from magnesite which has been thoroughly dead-burned.

The porosity of magnesia brick averages from 24 to 30 per cent, but may be somewhat higher or lower than these figures, depending upon the method of manufacture. The possible influence of this factor upon other properties should always be considered in making physical determinations. Low porosity is desirable where brick is to be used in contact with slag, in order to minimize slag penetration. As pointed out by Simonis² the thermal conductivity is affected by the porosity. Mellor³ is of the opinion that high porosity facilitates spalling by permitting excessive shrinkage at high temperatures; however, American experience seems to justify the conclusion that under most conditions a porous brick spalls less than a dense one.

Crushing Strength.—Magnesia bricks are much stronger in the cold condition than other refractory bricks, a fact to be explained, in part at least, by their high flux content and high temperature of burning. For materials of American manufacture, the crushing strength of magnesia brick on flat ranges from 5000 to 8600 lbs. per sq. in.; that of first quality fire-clay brick from 1600 to 3500; that of silica brick averages 2600. The strength on edge and on end will in each case average 30 to 40 per cent less than these figures.

While very strong when cold, magnesia brick will not sustain a heavy load at high temperatures. Le Chatelier and Bogitch⁴ state that the brick which they have tested all show an abrupt decrease in hot crushing strength at temperatures depending on

¹ J. W. Mellor, "Spalling of Magnesite Brick," *Trans. Ceram. Soc. (Eng.)*, **16**, 85 (1916-1917); *Eng. Mining J.*, **104**, 229 (1917).

² M. Simonis, "Contribution to the Heat Conductivity of Firebrick," *Sprechsaal*, **41**, 547 (1908).

³ *Op. cit.*

⁴ Le Chatelier and Bogitch, "The Refractory Properties of Magnesia," *Trans. Ceram. Soc. (Eng.)*, **17**, Pt. I, 18 (1917-1918).

their degree of purity. With one brick this occurred between 1300° and 1400° C; while with a purer one it took place between 1500° and 1600° C.

G. H. Brown¹ found that brick made of Austrian magnesite, set on end and heated, with a constant load of 50 pounds per square inch, failed suddenly at 1550° C with no previous evidence of contraction or softening. The brick sheared off diagonally into two parts much like a break resulting from a cold crushing test. Chrome brick, under the same conditions, failed suddenly at 1450° C.

Brick made from Washington magnesite will shear at temperatures from 1410° C to 1555° C, depending upon the composition and treatment of the crude material.² The lime content has a very marked effect upon the behavior of the brick in the load test. This has been shown by heating two bricks of the analyses given below at the rate of 250° C temperature increase per hour, under constant pressure of 25 pounds per square inch applied to the ends. The brick, which contained 15 per cent of lime, began to soften at 1300° C, and had compressed 12.5 per cent of its original length by the time 1475° C was reached. The brick with only 3.2 per cent of lime did not soften nor compress appreciably, and sheared suddenly at 1555° C.

ANALYSES OF BRICKS SUBJECTED TO LOAD TESTS AT HIGH TEMPERATURES

| | Washington magnesite | Canadian magnesite |
|-------------------------------------|-------------------------|-----------------------|
| MgO..... | 82.40 | 70.84 |
| CaO..... | 3.18 | 15.05 |
| SiO ₂ | 7.26 | 5.72 |
| R ₂ O ₃ | 7.09 | 7.94 |

According to Mellor and Emory³ magnesia brick whose fusion point was above 1920° C, when heated under a load of 50 pounds per square inch, first deformed slightly and suddenly collapsed at about 1500° C. Chrome brick behaved in the same manner

¹ G. H. Brown, "Load Tests on Magnesia, Chrome and Silica Brick," *Trans. Am. Ceram. Soc.*, **14**, 391 (1912).

² McDowell and Howe, "Basic Refractories for the Open Hearth," *Trans. Am. Inst. Mining Eng.*, **55**, 291 (1919).

³ Mellor and Emory, "Effect of Load on the Refractoriness of Fire-bricks," *Gas J.*, **142**, 478 (1918).

at about 1400° C. Zirconia brick, under a load of 25 pounds per square inch, "squatted" at about 1600° C, and under 75 pounds per square inch, at 1420° C. As determined by Le Chatelier,¹ silica brick made in America have a crushing strength of over 500 pounds per square inch at 1500° C.

Specific Heat of Magnesia Brick.²—The specific heat of brick composed of 88.85 MgO, 0.35 CaO, 0.20 SiO₂, 9.31 Fe₂O₃, and 0.17 Al₂O₃ is given by E. Heyn as follows:

| t ° C | True specific heat at t ° C | Mean specific heat between 25° C and t ° C |
|---------|----------------------------------|--|
| 0 | 0.208 | ... |
| 100 | ... | 0.220 |
| 200 | .253 | .233 |
| 400 | .275 | .250 |
| 600 | .290 | .260 |
| 800 | .316 | .269 |
| 1000 | .324 | .278 |
| 1100 | .332 | .282 |
| 1200 | .340 | .287 |
| 1300 | .349 | .291 |

According to Steger,³ the mean specific heat between 20° C and 200° C of magnesia brick containing 84.5 per cent MgO, was 0.225. The values in the table are considerably higher than the figures for fire-clay brick, the specific heat of which corresponds to the following formula:⁴

Specific heat = $0.193 + 0.046t$, where t is expressed in degrees centigrade.

Thermal Conductivity.⁵—While the thermal conductivity of magnesia brick is generally recognized to be high as compared

¹ Le Chatelier and Bogitch, "The Manufacture of Silica Brick," *Trans. Am. Inst. Mining Eng.*, **60**, 134 (1919); *Compt. rend.*, **165**, 742 (1917).

² E. Heyn, "Thermal Conductivity of Refractory Building Materials," *Mitteilungen a. d. kgl. Material-prüfungsamt*, **32**, 185 (1914).

³ W. Steger, "The Specific Heat of Refractory Materials," *Silikat-Z.*, **2**, 203 (1914).

⁴ Wilson, Holdcroft and Mellor, "Specific Heats of Firebrick at High Temperatures," *Trans. Ceram. Soc. (Eng.)*, **12**, 279 (1912-1913).

⁵ E. Griffiths, "The Thermal Conductivity of Materials Employed in Furnace Construction," *Trans. Faraday Soc.*, **12**, 193 (1917). Hutton and Beard, "Notes on Heat Insulation," *Ibid.*, **1**, 264 (1905).

with that of the other common refractories, considerable difference exists in the results reported by various observers. In a few cases these results obviously disagree with known facts; in others, it is possible that differences in the methods used, as well as variations in porosity, specific gravity and impurity content of the brick, may account for the lack of concordance in the

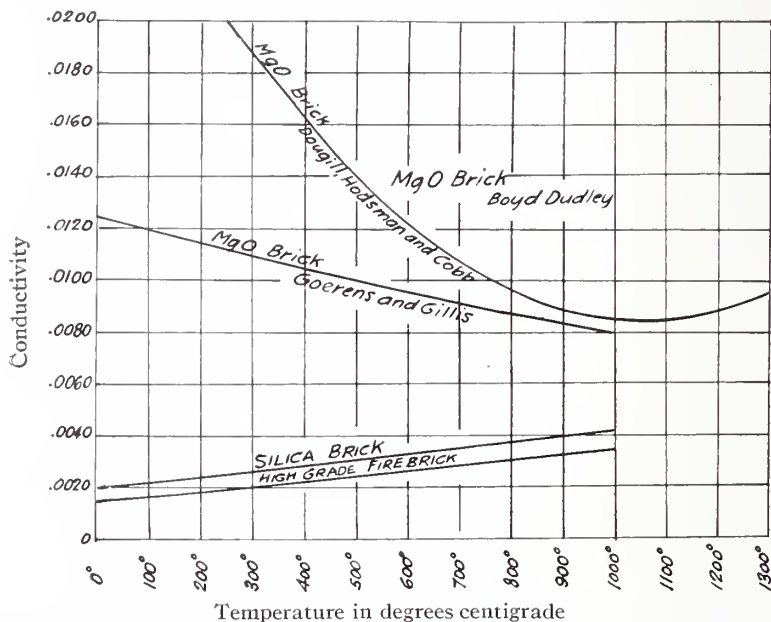


FIG. 2.—Thermal conductivity of refractories. Conductivity expressed in calories per 1° C temperature difference, per second, per square centimeter area, per centimeter thickness.

results. The conductivity seems to decrease with rise of temperature, contrary to that of silica and clay brick which are better conductors at high temperatures than at low.

The specimen studied by Boyd Dudley¹ (analysis: MgO 86.5, SiO₂ 2.5, Fe₂O₃ 7.0, Al₂O₃ 0.5, and CaO 2.75; volume density 2.46) had a constant conductivity between 445° and 830° C, and a coefficient within that temperature range of 0.0135 calories per

¹ Boyd Dudley, "The Thermal Conductivity of Refractories," *Trans. Am. Electrochem. Soc.*, 27, 285 (1915).

second, per sq. cm., per cm. thickness, per 1° C temperature difference. The same observer reports the mean conductivity between 0° C and 1000° C of "Star" silica brick to be 0.0031, and of Woodland clay brick 0.0025.

Goerens and Gillis¹ found the magnesia brick with which they experimented (analysis: MgO 86.42, SiO₂ 2.66, Al₂O₃ 6.47, Fe₂O₃ 4.45, lime —; volume density 2.34; true density 3.53; porosity 34 per cent) to have a mean coefficient of conductivity between 100° and 200° C of 0.0117; between 0° and 1000° C of 0.100; and true conductivity at 1000° of 0.0080. Their results may be expressed approximately by the formula:

$\frac{K^{\circ}}{1000^{\circ}} = 0.0124 - 0.0526(t_1 + t_2) + 0.092(t_1 + t_2)^2$, where K is the mean coefficient between any two temperatures t_1 and t_2 .

Dougill, Hodsman and Cobb,² working with a fine grained magnesia brick low in iron and branded "Mabor" (analysis: MgO 92.1, SiO₂ 5.0, Al₂O₃ 0.4, Fe₂O₃ 1.6, CaO 1.7; volume density 2.40; true density 3.51, porosity 31.4 per cent) found that the conductivity decreased rapidly with rising temperatures up to a certain point, and that it was represented closely by the formula:

$K = 0.0285 - 0.04379t + 0.07179t^2$ at any temperature t between 270° C and 1370° C.

According to this formula, the mean conductivity between 0° and 1000° C (by integration) is 0.0155; the true conductivity at 1000° C is 0.0085.

Electrical Resistivity of Magnesia Brick.—It is natural that interest in the electrical resistivity of refractories, especially those made of magnesia, has increased with the more general industrial application of the electric furnace, yet very little information on the subject is available. Stansfield, MacLeod and McMahon³ have compared the resistivity at high temperatures of silica, Austrian magnesia and chrome brick made in America, and firebrick from Caledonia. They state that the probable error of

¹ Goerens and Gillis, "The Thermal Conductivity of Refractory Materials," *Ferrum*, 12, 1, 17 (1915).

² Dougill, Hodsman and Cobb, "Thermal Conductivity of Refractory Materials," *J. Soc. Chem. Ind.*, 34, 465 (1915).

³ Stansfield, MacLeod and McMahon, "The Electrical Resistivity of Firebrick at High Temperatures," *Trans. Am. Electrochem. Soc.*, 22, 89 (1912).

their determinations is less than five or ten per cent for readings under 6,000 ohms, increasing to a maximum probable error of 25 per cent at 21,000 ohms; also that the results for chrome brick are subject to correction.

ELECTRICAL RESISTIVITY IN OHMS PER CM³

| Temperature °C | Magnesia brick | Chrome brick | Silica brick | Fire-brick |
|-------------------|-------------------|-----------------|-----------------|------------|
| 600 | ... | ... | ... | 21,000 |
| 700 | ... | ... | ... | 17,000 |
| 800 | ... | 2,800 | ... | 13,000 |
| 900 | ... | 760 | ... | 9,000 |
| 1000 | ... | 420 | ... | 6,600 |
| 1100 | ... | 430 | ... | 4,400 |
| 1200 | ... | 450 | ... | 2,300 |
| 1300 | 6,200 | 410 | 9,700 | 1,300 |
| 1400 | 420 | 320 | 2,400 | 690 |
| 1500 | 55 | ... | 710 | 280 |
| 1550 | 30 | ... | 22 | 60 |
| 1565 | 25 | ... | 18 | .. |

Thermal Expansion of Magnesia Brick.—Data from three sources¹ are available on this subject, and the close agreement in the figures given is unusual when the variety of raw materials involved and the difference in methods are considered. Not only do the three investigators check each other closely, but the results also justify the common practice in laying of allowing about $\frac{3}{16}$ inch per foot (or 1.56 per cent) for expansion.

PER CENT LINEAR EXPANSION OF MAGNESIA BRICKS

| Source of raw material | Observer | °C | | | | | | | |
|---------------------------|-----------------|------|------|------|------|------|------|------|------|
| | | 200 | 400 | 600 | 800 | 1000 | 1200 | 1400 | 1600 |
| Washington.. | S. M. Phelps | .. | .. | .. | 1.04 | .. | .. | 1.95 | .. |
| Washington.. | S. M. Phelps | .. | .. | .. | .90 | .. | .. | 1.81 | .. |
| Austria..... | LeChatelier | 0.21 | 0.55 | 0.85 | 1.10 | .. | .. | .. | .. |
| Greece..... | LeChatelier | .25 | .52 | .79 | 1.02 | .. | .. | .. | .. |
| Austria..... | R. H. H. Pierce | .25 | .46 | .57 | .79 | 1.08 | 1.50 | 1.88 | 1.88 |
| Average..... | | .24 | .51 | .74 | .97 | 1.08 | 1.50 | 1.88 | 1.88 |

The expansion curve of commercial brick made in America, as determined by Pierce, is shown in figure 3. He observed that expansion ceased at about 1350° C. and that contraction took place above 1600° C.

¹ R. H. H. Pierce, private notes, Harbison-Walker Refractories Co.; S. M. Phelps, private notes, Mellon Institute of Industrial Research.

Other observers have noticed that magnesia brick sometimes shows a permanent contraction after reheating to high temper-

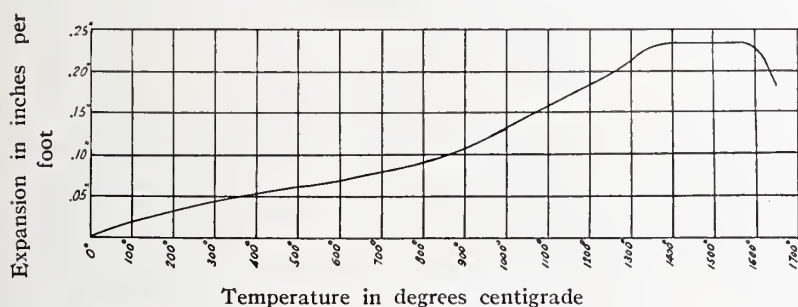


FIG. 3.—Thermal expansion of magnesia brick, made from Austrian magnesite.

atures. After reburning to the highest temperature of the porcelain kiln, certain brick made in Austria showed the following permanent shrinkage:

| Reburn | Linear shrinkage per cent | Total linear shrinkage per cent |
|---------|------------------------------|---------------------------------------|
| 1 | 0.36 | 0.36 |
| 2 | .31 | .67 |
| 3 | .13 | .80 |
| 4 | .08 | .88 |

Mellor found that a British magnesia brick, of slightly lower true specific gravity than the average American product, showed a marked contraction on the heated end when subjected to the heat of the Rennerfelt electric furnace. Of the total contraction, 6 per cent was attributed to the shrinkage of the magnesia, and the remainder, 9.8 per cent, to the closing of the pore space.

Thermal Expansion of Magnesia Bricks under Pressure.—This data was obtained at the laboratories of the Mellon Institute by heating magnesia brick at the rate of 250°C per hour under a constant load. The total expansion of the brick, pressure rods, furnace, and so forth, was first noted and recorded. The incidental expansion of the furnace parts was obtained by subjecting silicon carbide brick to similar treatment and allowing for the known expansion of these bricks. This incidental expansion was subtracted from the total expansion and the remainder attributed to the magnesia brick.

Four magnesia brick showed an average linear expansion of 0.96 per cent at 800° C, and 1.94 per cent at 1200° C, under a pressure of 25 pounds per square inch. It will be observed that these figures do not differ appreciably from the expansion under no load.

Chemical Action Between Magnesia and Fire-clay or Silica Brick.—The fact that magnesia enters into chemical combination at high temperatures with fire-clay and silica refractories has been known for a long time. The reaction is less violent, and takes place at higher temperature, with silica brick than with fire-clay brick; hence, magnesia brick is often used in furnace walls in contact with the former, but should be separated from clay brick by a neutral course such as chrome. Bischof¹ observed that fireclay and magnesia react at a temperature estimated to be about 1600° C, with the formation of a very fluid gray slag which rapidly penetrates a fire-brick.

The subject has recently been studied in the following manner:² Small pats or discs of refractory material were made in semi-circular sections, separated by a thin joint of chrome. One section, which held standard pyrometric cones, consisted of fire-clay; the other section, in which chips of fire-brick or silica brick were placed, was made of dead-burned magnesite. The pats were placed on chrome pedestals and heated at such a rate that succeeding standard cones melted at three hour intervals. The results obtained are expressed in the following table:

| REACTING TEMPERATURES BETWEEN MAGNESIA AND FIRE-CLAY OR SILICA BRICK | | |
|---|-------------------------------|-------------------------|
| Material ³ | First quality fire-clay brick | Silica brick |
| Dead-burned magnesite containing 3 per cent CaO..... | Cone 20 (about 1530° C) | Cone 26 (about 1610° C) |
| Dead-burned magnesite containing 15 per cent CaO..... | Cone 18 (about 1490° C) | Cone 18 (about 1500° C) |

¹ Bischof, "Magnesite Brick," *Oesterr. Z. Berg-Hüttenw.*, 41, 27 (1893); *J. Iron Steel Inst.*, 49, Pt. I, 212 (1893).

² McDowell and Howe, *op. cit.*

³ Complete analyses given on page 222.

The temperatures indicated in the table as the fusion points of the pyrometric cones are those obtained by heating at a standard rate of temperature increase; in this test the rate of heating was much slower, and it is probable that fusion of the cones took place 80°C to 90°C lower than the figures given.

A violent reaction occurred between high grade magnesite and fire-brick at cone 20, with the formation of a thin liquid. The behavior of the silica brick chips was remarkable in that they seemed to be unaltered by whatever action had taken place, while they had cut deeply into the magnesite, creating a small cavity.

PART VI. MICROSCOPIC STUDIES

It has been shown in the preceding pages that caustic burned magnesia is composed essentially of amorphous magnesia,¹ while the dead-burned material is largely periclase. Pure amorphous magnesia probably begins to be altered to periclase, the crystalline form of MgO , at 1200°C or slightly lower, but with extreme slowness; the higher temperature the more rapidly conversion takes place. In the commercial production of dead-burned magnesite, it is found that the temperature necessary depends upon the duration of the heating, the size of the lumps, and the texture and composition of the crude material. Certain impurities are known to have a catalytic effect in hastening the change; it has been observed that a magnesite high in iron, such as the Austrian, can be dead-burned at 1450° to 1500°C , while one low in iron and other impurities requires a temperature of 1600° to 1700°C , or even higher.

Kowalke and Hougen,² have studied the effect of varying the temperature of burning upon the microscopic texture of cylinders made of pure magnesia, mixed with $7\frac{1}{2}$ per cent SiO_2 , molded at 1500 pounds per square inch, baked in an electric furnace. Periclase and forsterite ($2\text{MgO}\cdot\text{SiO}_2$) were identified in these specimens. Very little forsterite was formed at temperatures below 1500°C .; it appeared first on the boundaries of the peri-

¹ See page 211.

² Kowalke and Hougen, "Crushing Strength of Magnesia-Silica Mixtures at High Temperatures," *Trans. Am. Electrochem. Soc.*, **33**, 215 (1918).

clase grains. As the temperature of burning was raised to between 1700° and 1800° C the forsterite crystals increased rapidly in number and size, and finally united to form a complete envelope about the periclase crystals. In specimens burned above 2000° C this envelope did not exist, but the forsterite had collected to form separate crystals; such specimens had a lower hot crushing strength than those in which the forsterite surrounded the periclase grains. The forsterite evidently acts as a bond to hold the periclase crystals together, and loss of strength occurs at a temperature which causes softening of the forsterite, or of the MgO-forsterite eutectic.

F. Cornu¹ found that Austrian magnesite brick consist essentially of periclase crystals with clear outer rims, but with their central portions filled with very minute black opaque particles having well developed cubic cleavage and identified as magnesioferrite ($\text{MgO} \cdot \text{Fe}_2\text{O}_3$). The later work of Cronshaw² indicates that this identification was probably correct. Cornu observed between the periclase crystals, a dark to yellowish brown vitreous cement formed from the impurities in the magnesite. This cement he considered to be a $\text{CaO-Al}_2\text{O}_3\text{-SiO}_2$ glass, and estimated its amount as 6 per cent. It seems to have been observed by no other worker.

Scott³ has pointed out that British magnesite brick show two well defined types of structure. The first is characteristic of brick containing iron oxide as the main impurity, the second of those in which the main impurities are silica and lime. Both forms of crystallization are sometimes found in the same brick, but one or the other usually predominates, depending on the character of the impurities.

Thin sections of type one consist essentially of polygonal crystals of periclase, forming a reticulate aggregate, and often with

¹ F. Cornu, "On the Composition of Magnesite Brick, Especially their Content of Periclase," *Z. prakt. Geol.*, 16, 449 (1908); quoted by F. Redlich in Doelter's "Handbuch der Mineral Chemie," 1, 253 (1912).

² H. B. Cronshaw, "A Curious Mineral Occurring in a Magnesite Brick," *Trans. Ceram. Soc. (Eng.)*, 16, Pt. I, 101 (1916-17).

³ A. Scott, "Note on the Microstructure of Magnesite Bricks," *Ibid.*, 17, Pt. II, 475 (1917-18).

well-defined cleavage. The periclase crystals contain inclusions of small, dark grains of magnesioferrite, and are usually brownish to red. This color was believed to be caused by iron oxide or by a ferrate of magnesium in solid solution with the periclase. The impurities other than the iron crystallize mainly as silicates, forming doubly refracting areas between the periclase grains.

In type two the periclase occurs in the form of rounded grains, extremely variable in size, and very rarely containing magnesioferrite inclusions. The polygonal structure of type one is absent, and adjacent periclase granules are usually separated by layers of impurities. These form a ground mass of variable composition, sometimes showing traces of glass but generally crystalline. Lath-shaped crystals of high double refractions, apparently forsterite, may be observed; a mineral resembling monticellite is more common.

Scott believes that brick showing the first type of crystallization is more refractory than that showing the second, owing to the higher percentage of silicates in the latter, and observes that a brick containing appreciable quantities of monticellite would have a molten ground-mass at furnace temperatures.

According to W. Donald¹ the formation of periclase occurs more rapidly and uniformly the more uniformly the impurity is distributed throughout the magnesite; the impurities should not merely coat the larger fragments but should interpenetrate them. Very pure magnesite of the dense variety, calcined in the electric furnace, was studied under the microscope. It was observed that each grain was completely transformed to periclase at the outer edges where it was in contact with impurities; next to this was a fine grained band into which crystallization was penetrating, and the interior of the grain consisted of a core of amorphous magnesia. Styrian brick from Veitsch were found to have a very uniform section with a homogeneous ground-mass. The larger particles did not exceed one-eighth inch in diameter and consisted of 150 to 180 small periclase crystals whose borders were separated by thin films of impurities. In British brick made

¹ W. Donald, "Magnesite and Magnesite Bricks," *Trans. Ceram. Soc. (Eng.)*, 17, Pt. II, 494, 521 (1917-18).

from Grecian magnesite the impurities were seen to surround and coat the fragments, but not to penetrate them.

C. R. Fettke¹ has compared the microscopic structure of a brick made from Washington magnesite with that of one manufactured before the war from Austrian material. The former was made from magnesite which had been dead-burned in a rotary kiln with the addition of sufficient iron oxide to bring the R_2O_3

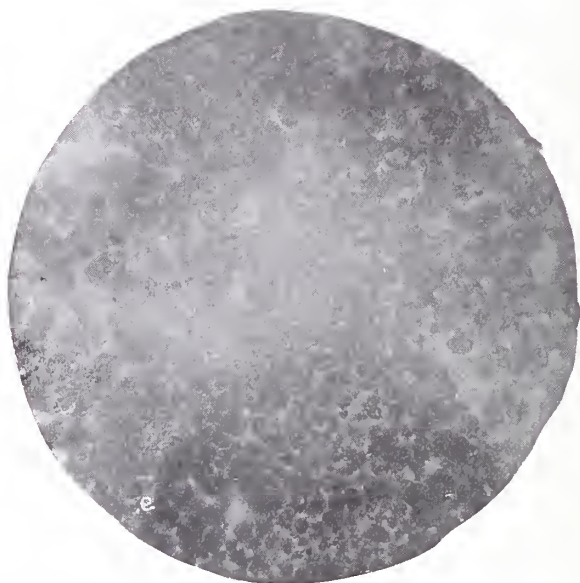


FIG. 4.—Photomicrograph of brick made from Washington magnesite (Fettke) Ordinary light. $\times 104$.

content to 7.0 per cent. Under the microscope the larger fragments in the brick can be readily distinguished from the finer grained matrix. A few of these fragments are 1.0 mm. in diameter, but the average are under 0.6 mm. The individual particles, both of the larger fragments and of the matrix, consist of granules averaging under 0.05 mm. in diameter, of yellowish brown color, occasionally with cubic cleavage; these granules were considered to be periclase, colored by iron oxide held in solid solution. Some

¹ C. R. Fettke, unpublished paper, 1918.

of the granules are free from inclusions, but a large proportion are rendered cloudy to nearly opaque by the presence of numerous inclusions too fine to be determined, but which are probably magnesioferrite. In the fragments the periclase granules interlock well, usually with only thin films of colorless silicates between them, although in a small proportion of the particles the percentage of silicates is high. In the matrix the silicates are more

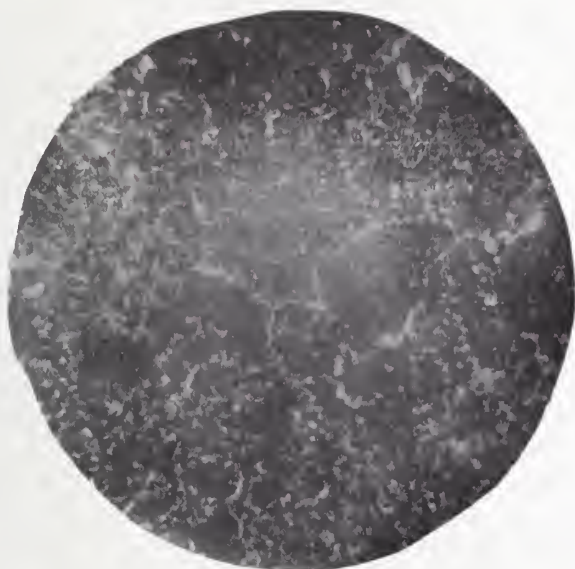


FIG. 5.—Photomicrograph of brick made from Austrian magnesite (Fettke). Ordinary light. $\times 104$.

abundant between the periclase grains than in the fragments, and they are occasionally concentrated in bunches. In a few cases the periclase appears to have reacted with the impurities, as the borders of some of the grains are doubly refracting. The silicates have the optical properties of the olivine group of minerals, members of which are monticellite, forsterite and olivine. No free iron oxide could be identified in the section.

The brick made of Austrian magnesite was slightly coarser in texture than the one just described, and some of the larger frag-

ments in the section have a diameter of 1.2 mm. Particles of both the fragments and matrix are composed of periclase granules, but the borders of these are not as distinct as in the brick of Washington material. In the fragments the granules reach 0.08 mm. in diameter, but they are smaller in the matrix. They are so full of minute dark inclusions (magnesioferrite?) that they are nearly opaque. In the fragments the periclase grains interlock well and silicates are practically absent. The granules of the matrix have a tendency toward roundness and are usually separated by silicates. In this brick the silicates are confined largely to the matrix, they are not so abundant as in the brick of Washington magnesite, the size of the silicate crystals is smaller, they are more uniformly distributed throughout the matrix, and they interlock better with the periclase crystals.

In a brick made from Californian magnesite, R. D. Pike¹ observed that the outer edge of the periclase grains was often clear, while the interior was rendered cloudy by numerous small inclusions. These were typical skeleton crystals, some of which were black and opaque, others reddish brown and translucent.

Mineralogical Note—Properties of Periclase, Magnesioferrite and the Olivine Group of Minerals²

PERICLASE: Composition, $\text{MgO} = 100$ per cent. Isometric, in cubes and octahedrons; usually colorless to grayish; cubic cleavage perfect. Hardness nearly 6; specific gravity 3.674; melting point 2800°C .

MAGNESIOFERRITE: Composition, $\text{MgO} \cdot \text{Fe}_2\text{O}_3 = \text{MgO } 20$ per cent Fe_2O_3 80 per cent. Isometric, in octahedrons, with and without truncated edges; opaque. In luster, color and streak it resembles magnetite and is strongly magnetic; hardness 6 to $6\frac{1}{2}$; specific gravity 4.57 to 4.65.

FORSTERITE: Composition, $2\text{MgO} \cdot \text{SiO}_2 = \text{MgO } 57.1$ per cent, SiO_2 42.9 per cent. Orthorhombic; color white, grayish, greenish. Hardness 6 to 7; specific gravity 3.21 to 3.33. Melting point 1890°C . No sharp line can be drawn between forsterite and chrysolite.

CHRYSLITE (OLIVINE): Composition, $2(\text{MgFe})\text{O} \cdot \text{SiO}_2$. Olivine grades into forsterite on the one side and fayalite ($2\text{FeO} \cdot \text{SiO}_2$) on the other; there is no sharp line of distinction on either side.

¹ R. D. Pike, Northwest Magnesite Co., private communication.

² Dana, "System of Mineralogy."

ANALYSIS

| | MgO | FeO | SiO ₂ |
|-----------------|------|------|------------------|
| MgFe = 9:1..... | 49.2 | 9.8 | 41.0 |
| MgFe = 5:1..... | 44.3 | 15.9 | 39.8 |
| MgFe = 3:1..... | 38.5 | 23.0 | 38.5 |
| MgFe = 2:1..... | 33.1 | 29.7 | 37.2 |

Orthorhombic; color usually green; hardness 6.5 to 7; specific gravity 3.27 to 3.57, increasing with the amount of iron present.

MONTICELLITE: Composition, $\text{CaO} \cdot \text{MgO} \cdot \text{SiO}_2 = \text{CaO}$ 35.9 per cent, MgO 25.6 per cent, SiO_2 38.5 per cent; iron replaces part of the magnesium. Orthorhombic; colorless, yellowish and greenish gray; translucent. Hardness 5 to $5\frac{1}{2}$; specific gravity 3.03 to 3.25.

Discussion.—The microscopic studies described above indicate that probably during the burning of the brick the iron oxide combines very slightly, if at all, with the other impurities of the magnesite, but that it enters into solid solution with the periclase crystals, and also combines with magnesia to form magnesioferrite. The latter separates out as minute inclusions within the periclase granules. The great value of the proper proportion of iron in magnesite evidently lies in its catalytic effect in hastening the formation of periclase.

Most magnesia brick contain alumina up to 1 or 2 per cent. The role played by this impurity is not definitely known, although there is reason to believe that alumina lowers the melting point of the bonding ground-mass of the brick, since clay, hydrated aluminum silicate, exerts a strong fluxing action on commercial magnesite when mixed with it even in small proportions.

The lime and silica impurities form silicate minerals evidently of the olivine group by combining with the necessary amount of magnesia. Forsterite, $2\text{MgO} \cdot \text{SiO}_2$, has been identified under the microscope by several observers. These silicates surround the periclase crystals and bond them together, and in small amounts may be necessary for the production of a well-bonded brick. To what extent they are needed is not clear, however, as it seems possible that if these impurities were almost entirely lacking, and sufficient iron oxide were present, a strong bond might be attained at kiln temperatures through interlocking of the periclase crys-

tals. J. B. Ferguson¹ has found that pure calcined magnesia powder, containing only 0.44 per cent silica, when heated for some hours in a small electric furnace at 1600° to 1700° C, formed a dense cake with considerable mechanical strength. A microscopic examination disclosed no bonding material; only interlocking periclase crystals, with less than 1/2 per cent of forsterite, could be identified. However, Kowalke and Hougen² have shown that cylinders made of MgO-SiO₂ mixtures are stronger at high temperatures with 7 1/2 per cent silica than with lower or higher amounts. It is interesting to note that in these tests the temperature of failure under a load of 66.5 pounds per square inch for mixtures containing 6 to 12 per cent SiO₂ varied from 1830° to 1870° C, temperatures very close to the melting point of the magnesia-forsterite eutectic.

The melting point of the magnesia-forsterite eutectic is 1850° C, and of the magnesia-lime eutectic 2300° C. In the ternary system CaO-MgO-SiO₂, the melting points and composition of the quintuple points bounding the forsterite field, and of one common to the periclase and monticellite fields, are as follows:³

| Composition | | | Melting point |
|-------------|------|------------------|---------------|
| MgO | CaO | SiO ₂ | |
| 22.3 | 37.3 | 40.3 | 1498° C |
| 26.4 | 32.1 | 41.5 | 1502° C |
| 22.3 | 33.3 | 44.4 | 1436° C |
| 20.2 | 29.8 | 50.0 | 1357° C |

It is evident from the figures given that when silica and lime are both present the melting points are much lower than when one or the other is absent; and that the relative proportions of lime and silica have a decided effect upon the fusibility. It is probable that in the burning of magnesia brick silicates whose melting points approximate the above figures are formed between

¹ J. B. Ferguson, "Note on the Sintering of Magnesia," *J. Am. Ceram. Soc.*, **1**, 439 (1918).

² O. L. Kowalke and O. A. Hougen, "Crushing Strengths of Magnesia Silica Mixtures at High Temperatures," *Trans. Am. Electrochem. Soc.*, **33**, 215 (1918).

³ Ferguson and Merwin, "The Ternary System CaO-MgO-SiO₂," *Am. J. Sci.*, **48**, 81 (1919).

the periclase grains. At furnace temperatures such silicates would be molten and the brick would then consist of periclase crystals, surrounded by a viscous mass of molten silicates saturated with dissolved magnesia. The amount of the viscous ground-mass would depend upon the quantity and relative proportions of lime and silica in the brick. This view is in accordance with the fact that magnesia bricks, although strong when cold, lose their strength and seem lacking in bond at high temperatures; and that when lime and silica are present in excessive amounts, their refractoriness and load carrying capacity are greatly reduced. Le Chatelier and Bogitch¹ reached the conclusion that the brick when heated behave "as if the impurities melt suddenly at a certain temperature, leaving the magnesia grains isolated in a molten magma. They are then in the same condition as wet sand and possess only a very weak mechanical resistance."

The field for investigation of the properties of dead-burned magnesite and magnesia brick, and of the possibilities of improving their commercial value, offers a number of attractive problems. The influence of texture and composition of the raw magnesite, and the effect of added impurities upon the properties of the burned product, are not thoroughly understood. How the change from amorphous magnesia to periclase crystals may be brought about most economically and completely, and the crystals bonded together to form a brick which will be strong at furnace temperatures, with minimum shrinkage and tendency to spall, are questions deserving much careful study.

Harbison-Walker Refractories Co., Pittsburgh, Pa.
Mellon Institute of Industrial Research, Pittsburgh, Pa.

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² In the preparation of this bibliography the standard journal abbreviations of the American Chemical Society (see *C. A.*, Dec. 20, 1915) have been used. Volume numbers are given in bold-faced type. For convenience of reference, the citations are arranged in chronological order.

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CLASSIFICATION OF CLAYS ON A CERAMIC BASIS

BY ARTHUR S. WATTS

The classifications of clays in use at the present time are a source of confusion to most of us, owing to the lack of any definite lines of division between the different groups.

Controversy is constantly arising as to the definition of a kaolin. Does it cease to be a kaolin when it is removed from its place of occurrence and is washed free of its associated minerals? If not, why should a kaolin washed by human devices be still a kaolin, while a material from the same mineral source and washed by nature in a manner almost identical with the artificial process cease to be a kaolin.

Dr. Heinrich Ries suggests¹ that the word "kaolin" be used in referring to "white burning clays of residual character, which are composed mostly of silica, alumina and chemically combined water and have a very low content of fluxing impurities, especially iron." He observes that in this country kaolin is formed chiefly by weathering of pegmatites, and in rarer instances from feldspathic quartzites, limestone and talcose schists while in Europe they are probably in most cases products of weathered granite and quartz porphyry. The term "kaolin" refers by this definition only to those residual clays burning white and containing low flux content. By this definition portions of our American kaolin deposits which do not burn white are not kaolins.

Similar type of controversy arises in connection with the term "ball clay." Ries,² who has given this matter much careful consideration, includes under this term all "white burning plastic clays of sedimentary character which are extensively used as a necessary ingredient of whiteware mixtures in order to give the body sufficient plasticity and bonding power. They must, therefore, contain little or no iron oxide and possess good plasticity and tensile strength." He places no refractory limit,

¹ "Clays, Occurrence, Properties and Uses," p. 200.

² *Ibid.*, pp. 203-4.

observes that some ball clays require washing before being marketed and also notes that Missouri ball clays are residual. The term is developed from the use to which certain clays are applied, and is extremely vague. For example, the term "white burning" as applied to kaolins cannot be the same as when applied to ball clays, although the expression is the same.

The term "fire-clay" is even more vague than either "kaolin" or "ball clay." Ries¹ says that the term "properly speaking, refers to those clays capable of withstanding a high degree of heat." He laments its misuse and observes that in the absence of standards of refractoriness the term is frequently misapplied. He suggests that the term should be applied only to clays fusing above cone 27, and that it does not signify the presence of any other property except refractoriness. According to this definition the term "fire-clay" includes most kaolins and many ball clays. In most American literature the term "fire-clay" is understood to refer to a "coal measure clay" regardless of its refractoriness.

The Proposed Classification

This confusion in technical literature will continue until a classification is introduced based on the ceramic properties of the clays. Such a classification would not presume to so identify a clay that it could be duplicated. It would not attempt to physically classify clays in the sense that a chemical analysis indicates the chemical composition. It would, however, give the reader a general understanding of the physical behavior of the clay so that no serious results could come from limited substitution.

The ceramic classification could be based on not to exceed five properties, *viz.*: color, shrinkage, bonding strength, vitrification and fusion. The last two properties could, if desired, be combined under the term "refractoriness" but in the writer's judgment this would distinctly weaken the system. They must, however, be jointly considered for a proper classification of any clay.

Color need only be classified sufficiently to subdivide those shades closely related to white. The use of the four terms white, cream, buff and tan are sufficiently distinct in the minds of most

¹ "Clays, Occurrence, Properties and Uses," p. 205.

people so that only in a limited number of cases would confusion occur. Beyond this classification the use of distinct colors, as red, brown, and so forth, could be used.

Shrinkage should be subdivided into drying and total shrinkage. These are normally understood to refer to the decrease in linear dimension from the plastic state to the bone dry state and from the plastic state to some definite burned state. The shrinkage at cone 10 is very commonly used in advertising potter's clays and it is sufficiently high to indicate any abnormal flux content. The term "plastic state" is generally understood to signify that normal water content which will enable the mass to be molded into smooth, sharp edged shapes. The determination of volume shrinkages is recognized as more accurate than linear shrinkages; but the shrinkage of a horizontal face is within the necessary limits for general classification, which is all that is here proposed. Both drying and total shrinkage should be expressed in per cent of the original volume.

Primary kaolins, flint fire-clays and sandy clays generally have a drying shrinkage of 3 to 5 per cent. Plastic fire clays and secondary white clays have a drying shrinkage between 5 and 8 per cent. Ball clays and very plastic shales have a drying shrinkage between 8 and 12 per cent and in extreme cases as high as 15 per cent.

On being burned to cone 10 the primary kaolins generally show a total shrinkage of from 9 to 12 per cent, the flint fire clays generally have a total shrinkage of 6 to 10 per cent, the secondary white clays have a shrinkage of 10 to 14 per cent and the ball clays have a shrinkage of 16 to 18 per cent.

It would appear practical, therefore, to subdivide the drying shrinkage of clays into five classes, *i. e.*, less than 3 per cent, 3 to 6 per cent, 6 to 9 per cent, 9 to 12 per cent, and more than 12 per cent. The total shrinkage at cone 10 could likewise be subdivided into those less than 4 per cent, 4 to 8 per cent, 8 to 12 per cent, 12 to 16 per cent and more than 16 per cent.

Bonding Strength.—Bonding strength should be determined with a mixture of equal parts by weight of clay and standard Ottawa sand. Bleininger and Schurecht¹ used a grog of calcined

¹ U. S. Bureau of Standards, *Bull.* 79.

flint fire-clay of the following sizes: 50 per cent between 20 and 60 mesh; 25 per cent between 60 and 150 mesh and 25 per cent through 150 mesh. They suggest the advisability of using a standard sand instead of this grog. Our Standards Committee suggest the use of standard silica sand between 20 and 28-mesh size in amount equal by weight to the clay.

The effect on the shrinkage of the blending of equal amounts of clay and sand is generally a reduction in drying and total shrinkage of about 40 per cent, provided the mass does not vitrify.

The transverse test has been found so much more satisfactory than any other means of determining the strength of the clay that the modulus of rupture as determined by this test and described in the Report of the Committee on Standards, 1919, pp. 40 to 43 inclusive, is recommended for this purpose. The same determination on a mixture of 50 per cent, by weight, clay and 50 per cent, by weight, non plastic (potter's flint recommended) gives a very reliable and satisfactory means of indicating the bonding strength of the clay.

The modulus of rupture for clays of high bonding power may be as high as 800 lbs. per sq. in. the white-burning secondary clays have values around 200 lbs., and the primary kaolins have values between 50 and 100 lbs. per sq. in. It would be practical, therefore, to divide clays on the basis of bonding power as follows:

Modulus of Rupture of 50 per cent Clay-50 per cent Flint Mixtures

- (1) Those having a modulus of 800 lbs. per sq. in. or more—High
- (2) Those having a modulus of 400-800 lbs. per sq. in.—Medium high
- (3) Those having a modulus of 200-400 lbs. per sq. in.—Medium
- (4) Those having a modulus of 100-200 lbs. per sq. in.—Medium low
- (5) Those having a modulus of less than 100 lbs. per sq. in.—Low

Vitrification.—This term is understood as referring to that state in which the clay shows no absorption. This determination is difficult with most clays. If, however, the absorption is determined on the clay when burned at two or more temperatures, the temperature at which it becomes non-absorbent can generally be estimated with reasonable accuracy by extrapolation. For best results at least one burn should be made at cone 10 or above.

Fusion.—This determination is explained under "Softening Point Determination"—Report of Committee on Standards, 1918, pp. 44 to 46, inclusive.

Vitrification and fusion data are to be expressed in Seger-Orton pyrometric cones. They may be divided as follows:

- (1) Vitrification occurs at cone 30 or above.
- (2) Vitrification occurs above cone 25 and below cone 30.
- (3) Vitrification occurs above cone 15 and below cone 25.
- (4) Vitrification occurs above cone 5 and below cone 15.
- (5) Vitrification occurs below cone 5.

Summary.

The entire classification can be made on the following chart:

CLAY CLASSIFICATION

| Date..... | Shipper..... | Location..... | | | |
|---|---------------|-----------------|-----------------|-----------------|----------------|
| Color: White, Cream, Buff, Tan. | | | | | |
| | Low | Medium low | Medium | Medium high | High |
| Shrinkage—drying..... | 0-3% | 3-6% | 6-9% | 9-12% | above 12% |
| Shrinkage total, cone 10.. | 0-4% | 4-8% | 8-12% | 12-16% | above 16% |
| Bonding strength, modulus of rupture, 50 per cent clay—50 per cent standard sand..... | 0 to 100 lbs. | 100 to 200 lbs. | 200 to 400 lbs. | 400 to 800 lbs. | Above 800 lbs. |
| Vitrification expressed in Orton cones..... | Below cone 5 | Cone 5 to 15 | Cone 15 to 25 | Cone 25 to 30 | Above cone 30 |
| Fusion expressed in Orton cones..... | Below cone 5 | Cone 5 to 15 | Cone 15 to 25 | Cone 25 to 30 | Above cone 30 |

The report on physical properties would be general enough so that the errors due to irregular sampling, variation of deposit with increased exposure, and so forth, would not cause danger of industrial error. If desired, the terms, low, medium low, medium, medium high and high could be used in reporting on the different properties, and in practically all cases would meet the requirements of the trade as well or better than more specific data on material not representative of the entire deposit.

THE ELECTRIC CLEANING OF METALS FOR ENAMELING PURPOSES

BY W. C. LINDEMANN

The enameling industry during the past few years has made radical changes in certain phases of the work, but probably the greatest changes have been, first, in the elimination of the old scaling process for removing grease with the substitution of chemical cleaning¹ and, second, in the use of new pickling agents to replace the old method of acid pickling. Certain individuals have advocated also the adoption of the electric method of removing grease, as practiced by electroplaters, to the cleaning of metals for enameling purposes.

The A. J. Lindemann & Hoverson Company for the past seven months has met with marked success in the application of the cleaning methods used in its electroplating department to its enameling process. This company is engaged in the enameling of sheet steel and cast iron in connection with stove manufacture.

Cleaning of Steel

A general description of the cleaning and pickling process is as follows: The metal in black shapes, as it comes from the presses, is immersed in an electric cleaning bath. The cleaning tank, which has a capacity of about 800 gallons, is made of metal and is connected to the positive pole of the generator. The solution is made of eight ounces of Wyandotte Metal Cleaner per gallon of water, and is maintained at the boiling temperature by the use of steam coils. Other cleaning agents have been used in place of the Wyandotte Cleaner and have given equally satisfactory results. Among these are Oakite Platers' Cleaner and Ajax Metal Cleaner.

The ware is suspended in the bath by means of metal hooks, hung from a bar which is used as the negative pole of the current. The current used is six volts direct current taken from a plating

¹ R. R. Danielson, "Cleaning of Sheet Steel for Enameling Purposes," *J. Am. Cer. Soc.*, 2, 883 (1919).

generator. The current flowing depends upon the amount of material put into the tank at one time, the density averaging about four amperes per square foot of metal surface being cleaned. The ware is left in this tank for from one to two minutes, although if left longer—as much as ten to fifteen minutes—no harm is done to the metal, but the current is wasted in unnecessary work. Saving in time is one of the recognized advantages of the electric method of cleaning. Ware under similar conditions but without the use of the current would require from twenty to forty minutes for proper removal of grease and oil.

After the electric cleaning, the ware is rinsed in clean, warm water and is then taken immediately to the pickling tank. The pickling solution is made of Cleanrite No. 2 in the proportion of five ounces of Cleanrite to each gallon of water. When not using Cleanrite, a three per cent solution of sulphuric acid is used, which also gives very satisfactory results. The solution in either case is kept at a temperature of 150° to 160° F, and the ware remains in the bath from five to fifteen minutes, depending on the condition of the metal.

After being pickled, the ware is given a rinsing in luke-warm water and then in two cold-water baths. A final rinsing is given in a neutralizing bath, composed of one-half ounce of Alkali Special to each gallon of water. This material is composed of approximately two parts of caustic soda and one part of soda ash and is more effective than the ordinary neutralizing bath consisting of a weak solution of soda ash, although the latter may be used. The ware is allowed to remain in the bath, which is kept at boiling temperature, a sufficient length of time to thoroughly heat it. This causes it to dry very quickly when placed in the steam-coil dryer. This completes the process of preparing the sheet steel for enameling, about two tons of ware being handled each day.

Cleaning of Cast Iron

The methods for cleaning the cast-iron ware are very similar to that for steel, the electric method as described above being used for removing any oils or grease. Following the cleaning the cast iron is rinsed and then pickled in an 8 per cent solu-

tion of hydrofluoric acid. The pickling bath is kept at temperatures of 150° to 180° F, and the ware remains in the bath for approximately fifteen minutes.

After the pickling, the castings are rinsed in lukewarm water, then in cold water, and finally in a boiling solution of borax. This borax solution is made of four ounces of borax per gallon of water. The borax serves two purposes, as a neutralizing agent for the hydrofluoric acid and to give a protective covering on the castings to prevent them from becoming oxidized or becoming dirty from finger marks. This protective coating is especially necessary if the castings are allowed to stand for any length of time before being enameled.

Conclusions

The results obtained with the electric process of cleaning have clearly demonstrated the advantages over the older scaling or burning-off method. Stated briefly, these advantages are: (1) Lower cleaning costs; (2) saving in time with corresponding greater output; (3) elimination of oxide sludge; (4) elimination of the sponging or scrubbing of ware, to remove the deposit of carbon formed during scaling.

The success of the electric method of cleaning has suggested the application of electricity to pickling. Experiments have shown that the ware so handled is put into better condition for enameling, but the process entails extra cost beyond the gain in condition of the metal.

Discussion

MR. JAEGER: In this method of pickling, do you have any trouble with blistering of steel?

MR. LINDEMANN: Many people use muriatic acid instead of sulphuric acid for pickling with good results, and some probably use stronger solutions than we do. We formerly used a sulphuric acid solution, ranging from 5 to 6 per cent, but reduced this to 3 per cent in accordance with a paper by Treischel in this JOURNAL on the effect of acid on blistering of steel.¹ We had consid-

¹ Chester Treischel, "The Cause and Control of Blistering in Sheet-steel Enameling," *J. Am. Ceram. Soc.*, 2, 774 (1918).

erable blistering with the 6 per cent acid solution but have practically eliminated it by the use of a 3 per cent solution. We have used different grades of steel during this time, and this may also account for the decrease in blistering; but we feel satisfied that the weaker solution has helped to control this trouble, and at the same time has resulted in a saving in acid with no appreciable difference in the time required for pickling.

THE TESTING OF CLAYS FOR CONCRETE AGGREGATE¹

BY D. H. FULLER

During the war, Mr. W. D. Richardson, of Columbus, Ohio, then with the Emergency Fleet Corporation, conducted a series of tests at this laboratory upon clays intended to produce, when fired, a light, vesicular mass, suitable for concrete aggregate. It is necessary that such clays be hard but overfired, containing a large volume of pore space so that fresh specimens will float in water. It is desirable also that the cavities be small and numerous rather than large and few. In fact, the more uniform the vesicular structure the more suitable it is for the purpose in view.

Material answering such requirements owing to its light weight and comparatively high strength when made up into concrete has certain possibilities for construction work where it is desirable to reduce the weight without proportionate loss in strength. It is evident that for this purpose shales and clays are most suitable, which produce the desired vesicular structure most readily, that is, overfire most easily. This pre-supposes the existence of a dense structure whether of the indurated or shale or the plastic clay type. The amount of carbon present is not a reliable criterion of the tendency to overfire as many very carbonaceous materials fail completely to produce the desired structure. It seems that the density of the clay structure, the amount and character of the carbon constituent and probably the presence of sulphates and sulphides are factors entering into the case.

It is not the purpose of this note to discuss the formation of the vesicular clay aggregate nor its manufacture on a commercial scale but to describe the method of testing materials for this purpose as practiced in the Pittsburgh laboratory. A large number of samples have been submitted for such tests and the simple

¹ By permission of the Director, Bureau of Standards

procedure might be of interest to other laboratories asked to do similar work.

From the exhaustive work of Mr. Richardson conducted on a large scale, it seems that rapid firing in rotary kilns represents the most feasible method of producing the aggregate. Hence to determine whether or not a clay or shale appears promising from this standpoint it need only be subjected to quick firing under heavily reducing conditions.

The method practiced in this laboratory consists in grinding the material, if a shale, through the 30-mesh sieve, followed by pug-ging to the condition of optimum plasticity, or by merely tempering the clay sample. Two-inch cubes are then molded by hand, then dried at room temperature and finally at 60° C. The specimens are next fired in a test kiln, heated by means of Fletcher burners, using natural gas and compressed air. The temperature of the furnace, as indicated by a protected thermo-couple, is raised according to the following heating schedule, under reducing conditions:

| Time, minutes | Temperature, C° | Time, minutes | Temperature, C° |
|------------------|--------------------|------------------|--------------------|
| 0 | ... | 210 | 1030 |
| 30 | 150 | 240 | 1075 |
| 60 | 300 | 270 | 1150 |
| 90 | 450 | 300 | 1225 |
| 120 | 600 | 330 | 1300 |
| 150 | 750 | 360 | 1375 |
| 180 | 900 | | |

It is necessary to provide openings for observing the outline of several of the cubes during the firing and for removing two specimens every 30 minutes after the temperature of 900° has been reached. These must be preserved for examination. In case decided bloating is observed at any one point specimens may be removed at shorter intervals, say 20 minutes. Upon the appearance of evidence of fusion the firing is, of course, stopped. Upon the completion of the run the gas is turned off and the furnace allowed to cool naturally.

The specimens are then examined to note the degree of bloating and tested by observing whether or not they float in water. By preparing several salt solutions (NaCl) between the specific gravities

of 1 to 1.1 the apparent density of the pieces can be quickly determined. The temperature at which bloating begins is to be noted as well as the point at which the most desirable structure is produced, which is determined by the floating behavior and the appearance upon breaking the specimen. The formation of a fine and uniform cellular structure is to be preferred to one consisting of large and irregular cavities. Materials which fail to float in the salt solution of specific gravity 1.1 or which consist of large cavities enclosed by a shell of dense, vitrified clay are not considered suitable for the purpose.

ACTIVITIES OF THE SOCIETY

The Story of the Twenty-second Annual Meeting

The influence of the Twenty-second Annual Meeting of the American Ceramic Society, which opened at the Bellevue-Stratford, Philadelphia, on February 23rd, will long be felt by those who were there. The opinion was generally expressed that the meeting was the best the Society had ever known.

A meeting of the Board of Trustees was called on Sunday afternoon at 2 o'clock. With the exception of Mr. Beecher, who was detained at home by illness, every member of the Board, together with the Secretary and the Assistant Secretary, was present. The usual routine business was transacted and the report was approved for submission to the Society. This report will be printed in the *Year Book*, so that it will suffice to say that it was of an optimistic nature and pointed out that the Society has experienced a year of unprecedented success. The financial position is secure and the membership is increasing. A second session of the Board was held on Sunday evening.

The Society as a whole met in the "Rose Garden" on Monday morning. There was a large attendance and more than the usual interest. Several members who had often been present in the early days but who had been missed recently now appeared and were warmly greeted. Langenbeck, somewhat grayer than of old, but his very self; Stover, who had been reported about ready for flowers, renewing his youth and energy; Burt, not quite so much of an absentee yet in nearly the same class, were among those present. Of the other presidents of the first decade there were Charles F. Binns, F. W. Walker, and A. V. Bleininger.

The president, R. T. Stull, opened the first session and delivered the annual address which was a plea for improved mechanical science in the manufacture of brick. He pointed out that 70 per cent of the cost of brick manufacture was in fuel and labor and that, while continuous kilns were strongly advocated for the saving of fuel, little had been done for the saving of labor.

The report of the Board of Trustees and the reports of Standing Committees were read and will be duly published. Mr. Minton, for the Committee on Papers and Program, made an interesting analysis of the gradually increased length of the program of the annual meeting and the percentage of members who contribute to it. The facts as shown are that in the early years of the Society about fifteen per cent of the members wrote papers; the last year has shown only three per cent. The recent rapid growth in membership is, of course, the immediate cause of this, but there is undoubtedly a tendency on the part of many members to "Let George do it," "George," in this case, occupying a settee, part of which is located in the colleges and part in the government bureaus.

A special committee had been appointed last year to formulate a definition of the word "Ceramic." Dr. E. W. Washburn, the chairman of this committee, was ready with the report which revealed excellent and painstaking work. The origin of the word was traced through Greek to Sanscrit, in which ancient tongue it had the significance of a substance developed by the aid of fire. Thus does primitive usage justify the interpretation which modern ceramists have placed upon their craft.

The afternoon of Monday saw the opening of the technical program. Certain papers of general interest were selected for presentation at this session but the main program was subdivided so that each of the Industrial Divisions might have its own group of papers. Consequently there were five simultaneous meetings on Tuesday and the work was rapidly disposed of.

On Monday night there was an innovation in the form of a Smoker and Section Q. This was held in the Clover Room and was attended by about 250 members and friends. There were singing and moving pictures but the stunt of the evening was pulled off by Professor J. B. Shaw and a number of Alfred students, who produced an original sketch entitled, "A Day in the Secretary's Office." Professor Shaw himself represented the Assistant Secretary, W. H. Reid, the Secretary, George Blumenthal, Jr., the office boy, and Messrs. Kenyon, Lobaugh, Collin, and Sherwood, four members who called at the office to make

complaints. Parodies of popular songs had been written and were given with much gusto.

On Tuesday night the banquet was held and was attended by nearly 160 persons. Round tables for twelve or eight had been provided and the members arranged themselves in congenial groups. F. W. Walker acted as toastmaster in his usual happy manner. Before calling on the speakers Mr. Walker indulged in some reminiscences of the early days and spoke of the men who, having founded the Society, carried it on until it was able to run alone.

The first speaker was Mr. Cattell, of Philadelphia, who delighted the audience with his eloquence and racy wit. He was succeeded by Professor Althouse, who delivered an address filled with inspiring thought and illustrated by humorous anecdotes. The toastmaster then called upon former presidents Bleining and Purdy, each of whom had words of value for the Society.

Wednesday morning had been set apart for a discussion on continuous kilns. This proved most attractive and the session was largely attended. So enthusiastic was the spirit that the meeting re-convened in the afternoon and adjourned only to leave time for the closing business session. The scrutineers of election announced the new officers: R. H. Minton, president; E. T. Montgomery, vice-president; R. K. Hursh, treasurer; and F. H. Riddle, trustee.

Thursday was devoted to sight-seeing. The local committee had with admirable energy and organization arranged trips in automobiles to industrial plants and other places of interest around the city. In the morning a party visited the Baldwin Locomotive Works and the O. W. Ketcham Terra Cotta Works, while a second group went to the plants of the Abrasive Company, the Philadelphia Textile Machinery Company, the Conkling-Armstrong Terra Cotta Company, and the Brown Instrument Company. In the afternoon some went to the Hog Island shipbuilding yards, and others visited points of historical interest and the Victor Talking Machine Company at Camden. An interesting trip was arranged on Wednesday afternoon for the ladies who attended the convention.

Too high praise cannot be given to the local committee, of which Frederick Stanger was chairman. A multitude of details had been worked out, and each event of the week passed off smoothly and enjoyably. Such efficiency removed untold burdens from the shoulders of the officers, and it is largely due to the efforts of the committee that the meeting was so marked a success.

CHAS. F. BINNS

Necrology

J. T. BRAMLETT.—Julian Troutman Bramlett, dealer in fire-clays, died of influenza pneumonia, complicated by meningitis on Feb. 27, 1920, at his home in Tallahatchie County, Miss.

Mr. Bramlett, who, until some four years prior to his death, was engaged in the drug business at Oxford, Miss., was born in 1881, and was educated in the school at Oxford, the University of Mississippi and the Louisville (Ky.) College of Pharmacy.

The property on which Mr. Bramlett's clay was located had been in the family for several generations, being a part of the estate of John Troutman, grandfather of Mr. Bramlett. No attempt had ever been made to put this clay on the market until 1916, when the European war created a demand for domestic clays. Mr. Bramlett, seeing the possibilities of development in the clay business, moved his family to Tallahatchie County and engaged in the business of mining clay. He was a member of both the American Ceramic Society and the National Brick Manufacturers' Association. He is survived by his wife, two small daughters, mother, father, two sisters and two brothers.

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EDITORIALS

AN ART DIVISION

Only a few years ago the ceramic products made in this country were not particularly remarkable for their beauty. They were good serviceable wares made from first-class material by skilled workmen; but, owing to the lack of judgment in choosing designs and decorations—or rather owing to failure to perceive that the proper choice of design and decoration were important factors in the selling price—the finished products were in many cases quite homely. It is true that such wares found a ready sale among certain classes of people. Up to the present time, this country has been a nation of pioneers; and, like all new nations, it has been interested primarily in producing the things which add to the material welfare and comfort of the people. Aesthetic development comes later in the life of nations. That homely, if not positively ugly pottery, was formerly highly prized in this country is evidenced by memories of the bric-a-brac on the “what-nots” of cold and gloomy “parlors.”

In the past twenty years the people of this country have made remarkable strides in the development of artistic taste and appreciation. This is shown in our architecture, our park and boulevard systems, in the dress of the people, and finally in a demand for more beautiful ceramic materials. As examples we may mention the ready sale found by high-grade terra cotta, the phenomenal development of the rough-texture face brick business, and the growth of the art and tableware potteries which have been turning out really beautiful wares.

At no time in the history of this country has the market price of beauty been as high as it is at present. The country is prosperous; thousands of people have the funds that enable them to satisfy the innate craving to possess beautiful objects. They are no longer satisfied to buy objects that are merely good and serviceable. They want them good and serviceable; but at the same time they want them beautiful and are willing to pay the price of beauty. The ceramic firms in this country which are making beautiful wares are finding that the care and expense involved in making their products beautiful instead of simply mediocre are very profitable investments. While there is still a market for homely wares, this market is decreasing; and it is safe to predict that it will continue to decrease very rapidly.

The ceramic industries of this country are second to none in the quality and serviceability of the wares they are manufacturing. If this country is to become one of the leading ceramic manufacturing countries of the world, it is essential that we cultivate the artistic side of ceramics. At the annual meeting in Pittsburgh the Board of Trustees of the American Ceramic Society authorized the formation of a Division devoted to ceramic decorative processes, provided ten members would ask for such a division. Nothing has come of this up to the present; but, for the sake of the best interests of the ceramic industries of this country, the American Ceramic Society should foster the development of the aesthetic phases of ceramics.

Our literature and membership lists disclose that many members of the Society are now working in the field of artistic ceramics—in the production of art pottery, both by factory methods as a business and by hand as an artistic craft, in the production of beautiful designs and glazes for terra cotta and wall tile, and in the designing and decoration of table ware and other ceramic products that must be beautiful as well as useful. It seems feasible to use these members as the nucleus of a potentially important Division devoted to artistic ceramics.

WORK OR QUIT

During the past few years the American Ceramic Society has been more fortunate than most societies in its committee work.

In nearly every case the work intrusted to a committee has been performed promptly and efficiently; and—what is more remarkable—in most cases a large portion of the committee members have actually helped in the work. In a few cases, however, the committees have done little and on every committee there have been a few members who have done nothing.

According to Webster a committee is a group of persons to whom some trust or charge is committed. We publish the names of our standing committees in the JOURNAL periodically, and thus advertise to the Society and to others that these men have undertaken to do certain things for the benefit of the Society. In the minds of the readers the members of these committees are given credit for doing altruistic work in the interest of the ceramic industries of this country. Committee members who do not work and who allow their names to be published in this way are receiving honor and gaining prestige by false pretense. Moreover, there is a sufficiently large number of members of the Society who are anxious to give energetic and faithful service to more than fill every committee. Therefore, these men are really standing in the way of the best interests of the Society. It seems, therefore, that if a member of the Society is appointed on a committee and, for any reason, he does not care to work or is not able to give the necessary service, he should promptly send in his resignation.

ORIGINAL PAPERS AND DISCUSSIONS

THE STORING AND HANDLING OF RAW CLAYS

By T. W. GARVE

Purpose of Storage.—We have pointed out in a previous paper¹ that "raw clays are stored for the purpose of sufficient supply during winter or during bad weather; to help over any breakdown at the mine or bank; to secure a better and more uniform mixture; and to improve the working conditions of the clay and the quality of the ware.

"The clay storage equipment should be an independent feature of the plant that can be in use continuously or intermittently, as conditions require, so that all unnecessary rehandling be avoided. It should face the clay bank, and later extension should be possible."

Crushing.—Shales are often crushed before being placed in storage and we have shown such layouts in our illustrations. This, however, may not have any bearing upon the system of storing and handling the clay or shale, hence the methods of storage can be considered by themselves.

If the shale is won by steam shovel there are frequently large pieces to go into the cars, and the sooner they are crushed the better for further handling. Where weathering or mixing are desirable or essential there will naturally be better results if the crushing is done ahead of the storing.

While it is recommendable to crush shales before their storage, it may be difficult to do so in certain cases, for instance, where

¹ "The Designing of Factory Layouts for the Clay Industries," *J. Am. Ceram. Soc.*, 2, p 194.

the factory is far from the storage intake and where no electric power is available. This difficulty might be overcome in certain installations by placing the crusher or any other grinding or preparing machinery at the factory end of the storage building where direct drives from the line shaft can be had, and conveying the crushed material backward to storage. In this way the direct use of unstored clay is easily accomplished.

Weathering.—Storing may have but little to do with weathering; and yet, to a certain extent, the process of handling and storing will more or less improve the working conditions of the clay and so the quality of the ware. Considering shales, the pre-grinding will be a factor in favor of the above claim.

It can readily be seen that by the methods of storing and handling we are opening up the raw materials and expose them more freely to the air just as we improve the soil by plowing it. A lot of air is being entrapped within the lumps or particles of shale or clay as they roll down over the storage pile to be rebuilt and repacked.

Mixing.—While there seems to be no real systematic mixing done by using a storage shed and dumping the clay down on piles, the result is often sufficient for practical purposes.

The storage alone would not be a sufficient means of mixing where it is essential to get an average of the clay bank from top to bottom and from end to end, and it will be necessary in such cases to get a mixture at the pit and work the clay or shale bank accordingly, by a clay digger, or shale planer, or hand method, or any other suitable manner. In any case, the material dumped will spread out in thin sheets over the storage pile, the voids being filled by the new layer, etc. This relaying of the clay bank so to speak, will unquestionably have a mixing effect to a degree determined by the manner of manipulation.

For mixing lengthways, it is an easy matter to have the clay car dump at different places along the shed or to set the tripper ahead at times or to use a continuously moving tripper which discharges along the storage while traveling back and forth. If there is a side discharge from car or belt, the sides can be altered at certain intervals. A certain amount of mixing again

is being done by drawing from storage. For perfect mixing or blending of different clays a method as shown in figure 10 may be used. A number of modifications can be worked out on this principle to suit the particular problem.

Clay to Storage.—The raw material can be taken to storage direct from a dump car, which can have a bottom, side or end discharge, or the car may be emptied by a dumping device. Since a dumping device would be a stationary affair, the dump car is to be preferred since it will permit of delivery at any place along storage. We can accomplish the same thing by the installation of conveyors of various types or, if the storage can be high without extending over a large area, a high elevator with a swivel spout, or distributing spouts might be used, or a rotating elevator. For more specific information see Conveying and Storage Systems.

Clay from Storage.—From storage the material can be carried out either by cars or suitable conveyors. For feeding the material to these, we can use removable boards or spouts or feeders of various types, as reciprocating feeders, disc feeders, or screw feeders. If boards are used, an opening, closed with removable boards, should be left at one end of storage building above the belt to enable the start of emptying a completely filled storage. For more specific information see Conveying and Storage Systems.

Belt Conveyors.—In regard to belt conveyors, the troughing type is used to quite some extent in clay plants, since it does not seem to spill the clay as the flat conveyor does and has greater capacity. However, the flat conveyor has its advantages, especially if used wide enough to prevent spilling of material. While a troughing conveyor will have about 60 per cent more capacity than a flat conveyor of the same belt, the life of a flat conveyor is considerably longer, perhaps half as long again.

The belt should be carried on idlers and not on boards. For a troughing conveyor, all idlers should be cylindrical and the side idlers should be set at an angle to form the trough of the belt, but no conical idlers should be used since their circumferential speed varies, causing rubbing and wear on the belt and shortening

its life. Large head and tail pulleys also will tend to lengthen the life of the belt. The belt speed should be around 125 feet per minute.

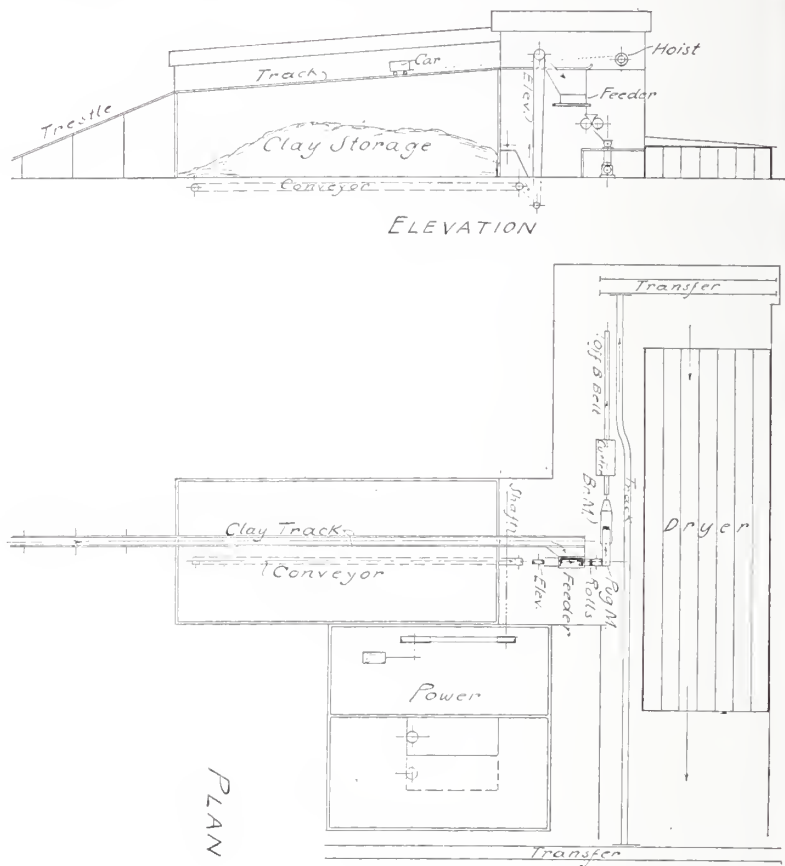
Conveying and Storage Systems.—In the accompanying illustrations we have a number of different systems for storing and handling raw clays or shales. Each has its merits and any preference would depend upon conditions, as capacity and location of plant, length of season, kind and quality of ware, kind of bank equipment and distance, character of material, kind of power equipment and its size, arrangement of factory, money available, and expenditure justified.

In figure 1 we have sketched a plant for making brick or tile to bring out again the independence as well as the relationship of the clay storage building with the rest of the factory. The car above the storage can discharge its contents at any place of storage or direct into the screw feeder for the factory. For using stored clay, the underground belt conveyor will be operated for charging the feeder mentioned. By means of movable boards above the conveyor duct, beginning from one end of storage, the material will slide down to the conveyor belt. This requires one man. This is not an expensive installation and will do well for a small or medium sized plant. It allows for extension by moving out the trestle.

A somewhat different system is illustrated in figure 2 where an elevator, receiving the raw or crushed material, delivers it through a chute either to the belt conveyor above storage or direct to the underground belt conveyor for direct use in the factory. The stored material can be dropped to the underground conveyor or be fed into the elevator at the factory at whatever height the storage level happens to be.

There are two modifications or improvements of this arrangement for the use of unstored clay, by either extending the underground belt conveyor to the left to receive the material direct without elevating it, or by extending the top belt conveyor to the right into the factory. Either scheme would eliminate one elevator for using unstored clay. These extensions are shown in dot and dash on the drawing.

Another method is shown in figure 3 where no conveying machinery is used and all transferring is done by cars. The



Cont. Kiln

FIG 1

stored clay is taken or scraped down from storage pile and shoveled into cars, and these cars are then returned to the front of the

trestle to be pulled up by winding drum over the storage pile to the factory over the same track from which the clay is dumped into storage.

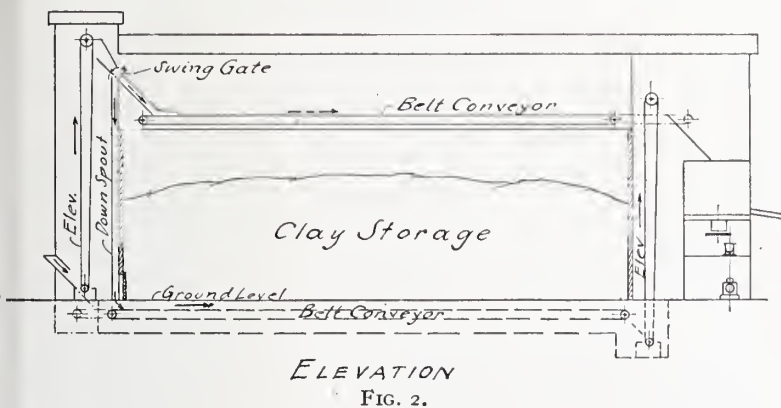


FIG. 2.

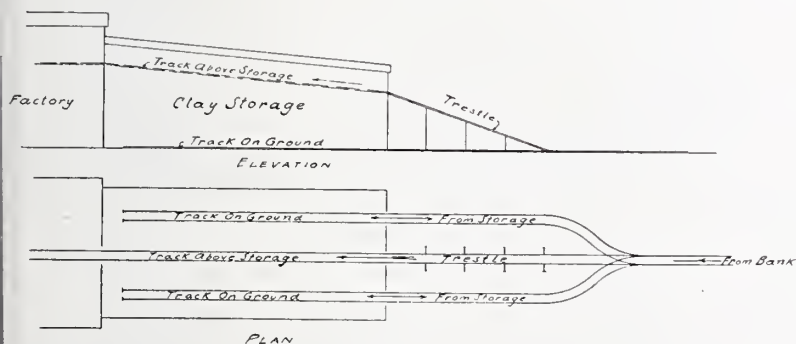
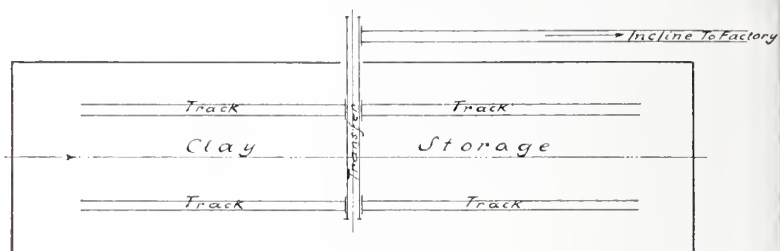


FIG. 3.

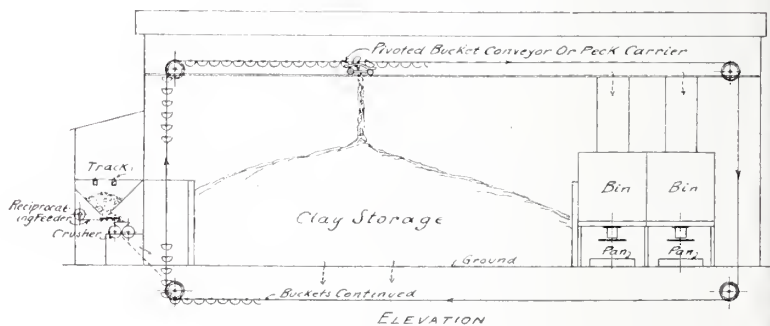
Figure 4 shows a somewhat different method for getting the clay from storage. The clay storage is divided into two piles at each side of the transfer track. The loading tracks are leading off to each side under the clay pile, and the clay is gradually worked down towards the end of each pile exposing more track as the emptying of storage proceeds. The inclined track to the factory is located to one side of the storage building and leads off from the transfer track.

In figures 5 and 6 we have two continuous systems for filling and emptying the storage. In the first system we have a continuous bucket conveyor or peck carrier, and in the second system



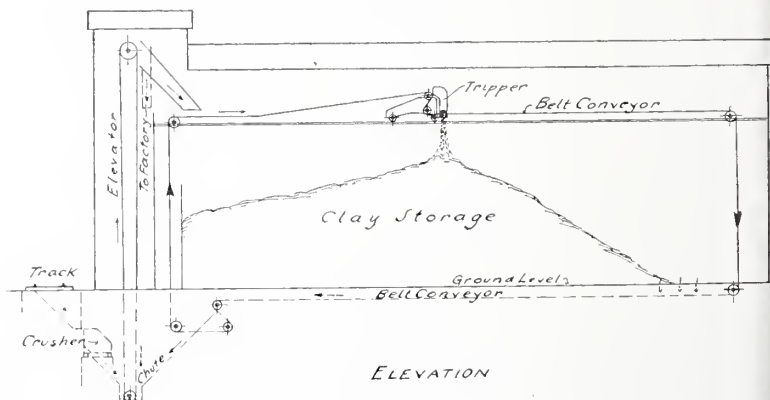
PLAN

FIG. 4.



ELEVATION

FIG. 5.



ELEVATION

FIG. 6.

the trick is being done by means of a continuous belt conveyor. They allow for carrying the material to storage or to the grinding plant by one continuous conveyor, operated from one drive. These installations are more expensive than the previous ones and require more power, but they are undoubtedly flexible and can be used to advantage in plants of large capacity or with large storage.

The elevator in the belt conveyor system can deliver the material direct to the factory, being right angle to storage, by turning the spout 90 degrees. The stored clay is delivered to the elevator at the opposite side of elevator boot.

A tripper, as shown, running on rails, is perhaps the best way for discharging a belt conveyor at a desired place, even though a tripper will add to the cost of the installation. Sometimes a scraper is used above the belt. A scraper will not clean the belt completely and some material will remain on the belt to be discharged at the end. The rubbing effect of the material on the belt behind the scraper will result in quite some wear on the belt.

Sometimes a drag conveyor is used as shown in figure 7 and

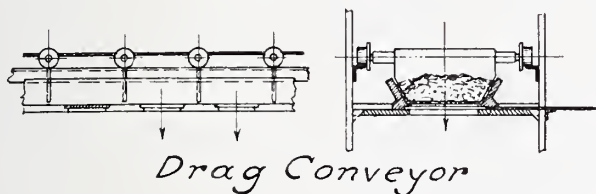


FIG. 7.

the clay is dumped through openings in the bottom or floor, and sliding gates are pulled out wherever the storage needs to be filled. Such a conveyor, single or continuous, can be used above and below storage.

Figure 8 represents a commendable system, initiated and fully described by Riddle in *Trans. Am. Ceram. Soc.*, Vol. XIX. The connecting link here between the dum pile and factory is a clamshell bucket attached to a crane. It allows piling at random with good mixing and can rightly claim flexibility.

In figure 9 we have a somewhat different system suggesting

round storage bins built of reinforced concrete or steel, being filled from a swivel spout of an elevator located in the center. Disc feeders at the bottom and one belt conveyor are to deliver

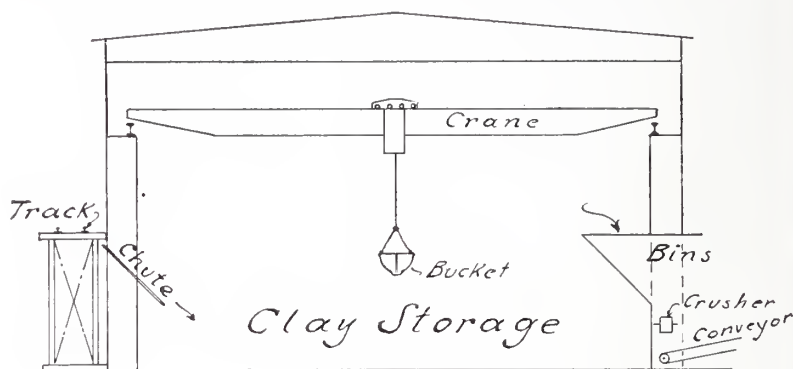


FIG. 8.

the stored clays to the factory. This system allows an excellent possibility for blending clays in proper and accurate proportions, and besides can be built within a small space. It can also be extended by adding more bins on the inside.

Returning Cars.—In order to return the car or cars from above storage, the track is sometimes sloped so that the cars including cable can return by gravity as shown in figure 3. Such a slope should be about one foot per 14 feet, or 7 per cent, but depends upon the conditions of the equipment.

Another way of returning cars automatically is to use a retriever as shown in figure 10. The extending loop near the upper end of the incline between rails is caught by a hook attached to the lower part of the car while being pulled up by the hoist. The car is pulled back by counterweights.

The counterweight shaft is connected with reducing gears to a cabledrum shaft which unwinds the cable attached to the car, pulling it back. The loop returns to its position between the rails when the car again passes this place on the upper incline on the return trip, the trip then being continued by gravity down

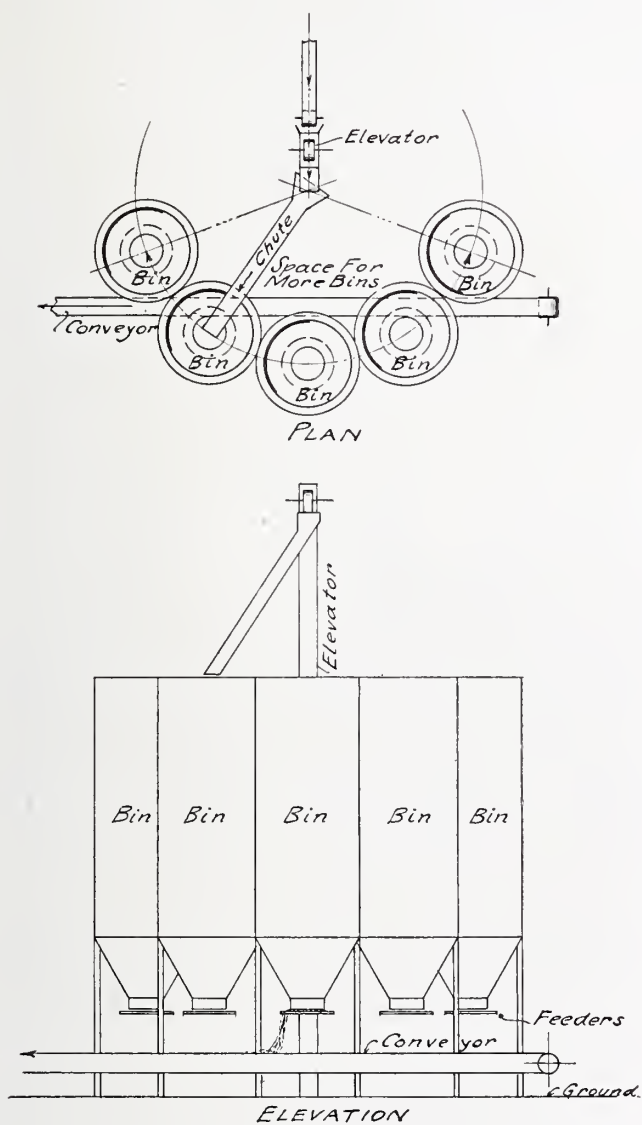


FIG. 9.

the incline. Instead of using counterweights, a second winding drum may be used for pulling the car back.

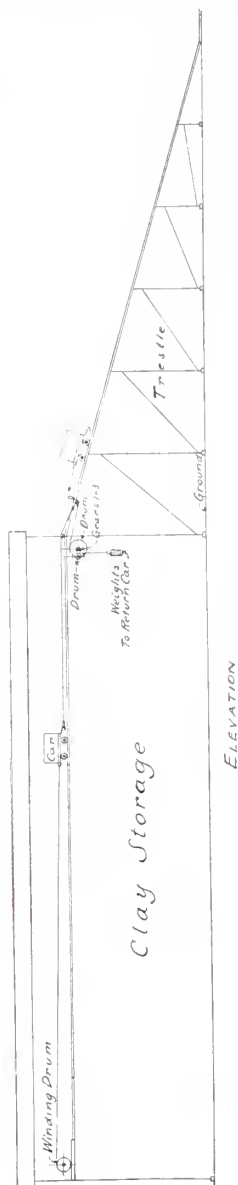


FIG. 10

ELEVATION

Sheds and Buildings.—The details must be worked out in every case for every plant, and it is not the place here to go into an elaborate discussion of them, and besides a number of them comprise the standards of an architect or engineer; however, in order to properly appreciate our storage problems and to allow comparison, it is necessary to throw some light upon some details of construction.

Before a clay storage shed of proper proportions can be designed, the angle of repose for the material in question should first be determined by experiment.

In figure 11 we have a cross section through a clay storage shed

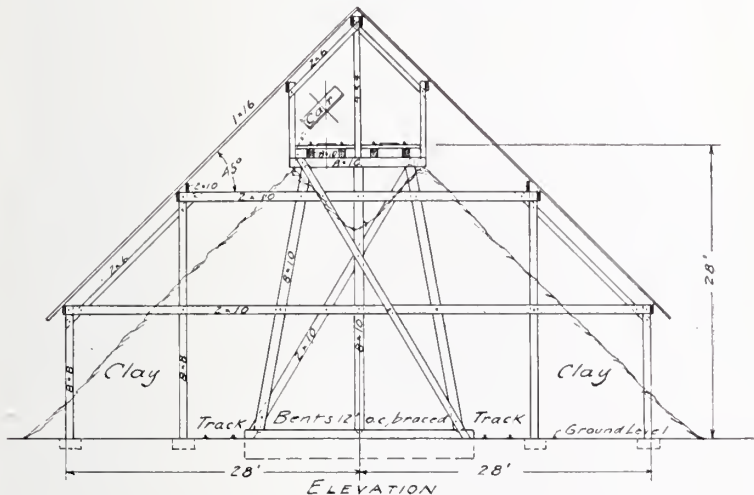


FIG. 11.

with a double track. It is put up of light timber and no rafters are used, instead the roof boards are placed at such an angle (at least 45 degrees), as to be self-supporting. It is a cheap construction, but has the disadvantage of much timber work within the clay pile with a tendency to breaking, due to unavoidable one-sided loading by clay. At the bottom the clay will roll out and form its own retaining wall. This shed requires about 7000 board feet of timber for 1000 tons storage capacity and is cheaper

than the other sheds mentioned later, mainly on account of the double track arrangement.

Figure 12 represents a single track shed of inexpensive and simple

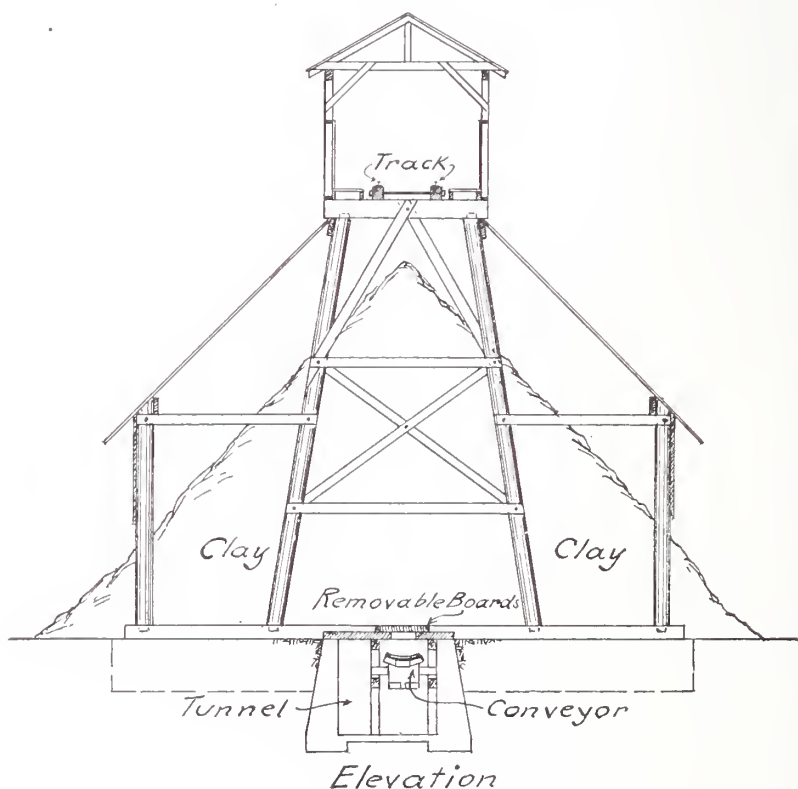
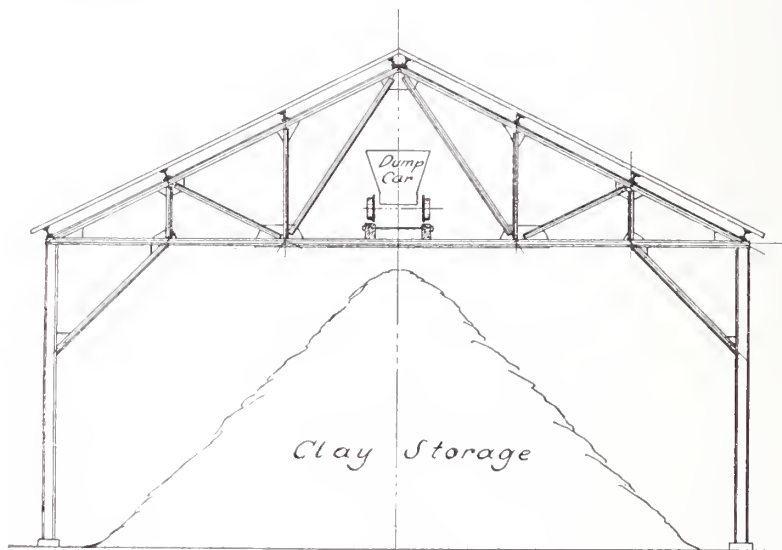


FIG. 12.

construction, well suitable for a small plant. The shed is, so to speak, built around the clay pile and little space is wasted. There are the self-supporting roof boards, but a heavier construction for the trestle.

For larger storage and where the angle of repose of the material is less steep, as, for instance, for coarse or perfectly dry material, a storage building as shown in figure 13 may be erected. The roof stringers are trussed, and they are resting on a concrete

steel, brick, or any combination of them. The following drawings of retaining walls are self-explanatory and hardly anything needs to be added.

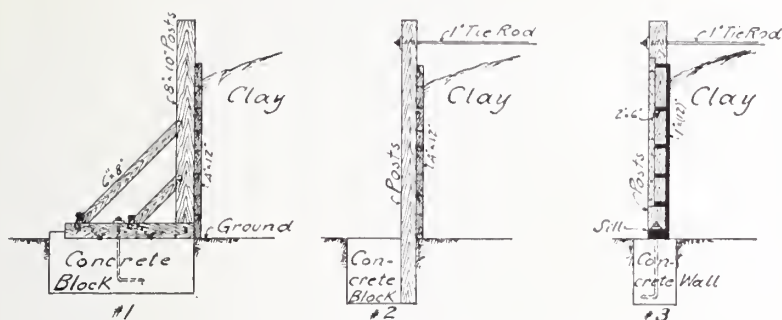


ELEVATION

FIG. 14.

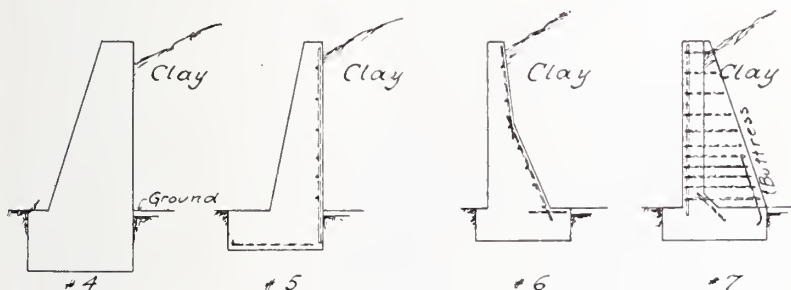
In figure 15 we have three representatives of frame retaining walls. In figure 16 we have plain concrete and reinforced concrete walls. This is not the place to go into a discussion of reinforced concrete design, which is a study by itself. We merely wish to mention that the steel bar reinforcements are placed where the wall is under tension. Figure 17 gives a retaining wall, using concrete, steel and timber. It is a strong construction and can be carried high. Figure 18 offers a suggestion for a wall built of steel and brick.

Retaining walls should be calculated to do the work and to be safe as the rest of the structure. While all these calculations are problems for the architect or engineer for the particular case, we wish to add a few words regarding the theory of retaining walls. There is a literature on retaining walls, and anyone interested can supply himself with much theoretical data.



FRAME RETAINING WALLS

FIG. 15.

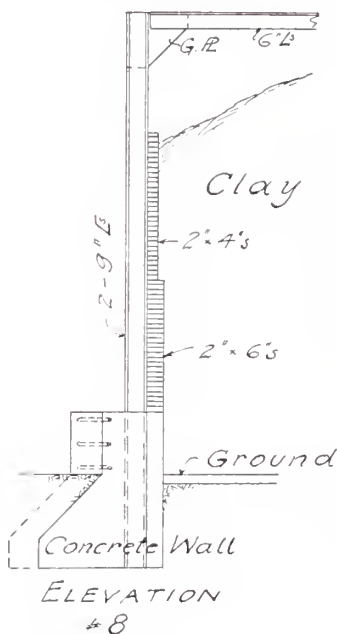


PLAIN AND REINFORCED CONCRETE RETAINING WALLS

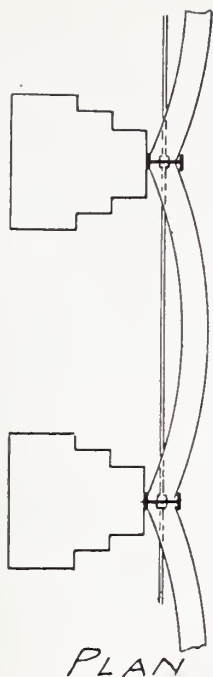
FIG. 16.

While there is a great variety of shapes of retaining walls for the many different purposes, we will assume that for the clay worker it dissolves itself into a wall with a straight and vertical back, a battered front, and a toe, as shown in figure 19.

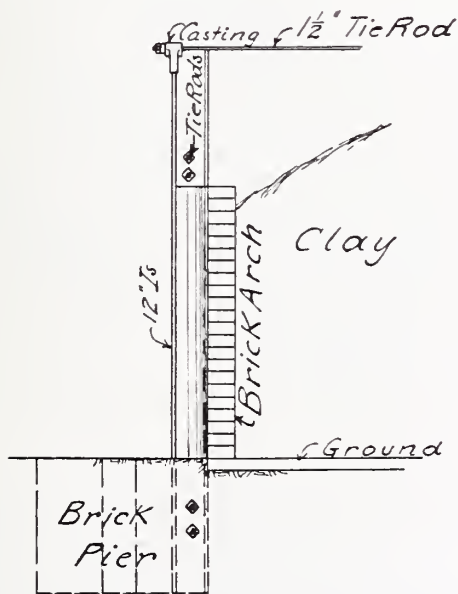
The wall must be strong enough in itself to prevent cracking or failure, it must be safe against overturning and safe against sliding. The clay behind the wall, tending to slide on itself and the surcharge, will tend to overturn it. The weight of the wall and footing or toe will be the resisting factors. The farther back we can keep the center of gravity of the wall the less it will tend to overturn. The soil pressure must be investigated, and if it is greater under the toe than the allowable unit pressure the base must be increased in area by extending the toe forward.



RETAINING WALL BUILT OF
CONCRETE, STEEL, AND TIMBER



PLAN



ELEVATION

9

RETAINING WALL BUILT OF
STEEL AND BRICK

FIG. 18.

There are a number of theories on the design of retaining walls; but assumptions have to be made here, and many engineers are guided by practical experience rather than by theoretical considerations. However, all the earth pressure theories assume that the surface of rupture behind the wall is a plane, that the point of resultant pressure is at one-third the height of the wall from the bottom, and that the resultant makes a definite angle with the horizontal.

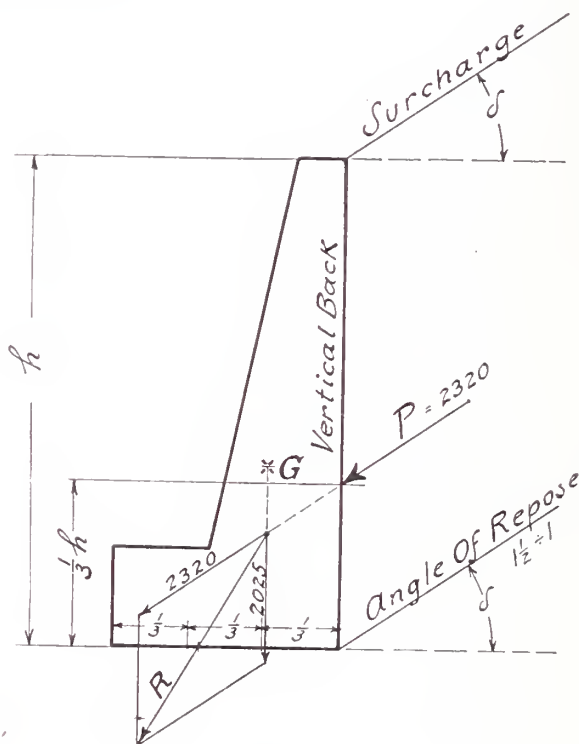


FIG 19

While there are, as mentioned, a number of theories, we wish to give here but a short and convenient method of checking the safety of a wall with a vertical back against overturning. The angles of repose and of the surcharge are assumed to be the same. The resultant earth pressure P then is parallel to these angles.

For this condition Rankine's formula receives the simple expression:

$$P = \frac{1}{2} w h^2 \cos \delta$$

where w is the weight of the filling per cubic foot

h is the vertical height of the wall in feet

δ is the angle of repose and surcharge.

In our case:

$$\begin{aligned} P &= \frac{1}{2} \times 100 \times 7.5 \times 0.83 \\ &= 2320 \end{aligned}$$

This represents the resultant earth pressure behind the wall for the length of one foot.

The weight of the wall per foot figures 2025 pounds.

The resultant R of these two forces should fall within the middle third of the base, which we find to be the case.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

THE EFFECT OF THE METHOD OF PREPARATION ON THE VISCOSITY OF A CASTING SLIP

BY V. S. SCHORY

Introductory

The properties of a casting slip are affected by a considerable number of variables. In developing a satisfactory composition for a casting slip it is necessary to take these variables into consideration and to improve the properties of a given casting slip by the selection of proper materials and by intelligent adjustment of the ingredients. The data necessary for this work can, of course, be obtained only by painstaking experiment. Having arrived at a composition which gives satisfactory results and which may be subjected to small variations without injurious consequences, the success of the casting process of manufacture is then largely dependent upon the elimination of variations as far as possible and upon their control by countering adjustments when they can not be eliminated.

When a casting slip is prepared from a ceramic body compound of feldspar, flint, china clay and ball clay the properties of the slip are dependent principally upon the following items: The ratio of the non-plastic ingredients to the plastic materials; the relative proportions of ball clays and china clays; the individual properties of each ball clay and china clay and the percentage of each clay used; the impurities naturally present in the clays and the foreign substances added to the clays in the process of preparation; the alkaline reagents used in the slip; the percentage of alkaline reagents—usually sodium carbonate and sodium silicate—used, and the ratio of the sodium carbonate to the sodium silicate; the percentage of water in the casting slip; the method by which the casting slip is prepared; the age of the slip; and its temperature.

The properties of a casting slip which it is desirable to maintain constant are: The specific gravity, the viscosity, the rate of casting, the firmness of the cast, the cleanness of drainage of

surplus slip from the cast, the strength retained by the cast, the hardening and drying of the cast in the mold and low shrinkage of the cast during the early stages of hardening and drying.

The viscosity of a casting slip is in itself of minor importance. The viscosity of a given slip may be varied by increasing or diminishing the percentage of alkaline reagents used or by varying its water content. As will be shown later, the viscosity depends also upon the method of preparing the casting slip. The more important desirable properties of a casting slip attain to their maximum development as a group at some definite degree of deflocculation as produced by the addition of suitable percentages of sodium carbonate and sodium silicate. This percentage of alkaline reagents may be increased or diminished only a small amount before unsatisfactory properties incident to excessive deflocculation or to insufficient deflocculation occur. For this reason it is not feasible to adjust the viscosity of a slip by changing the percentage of alkaline reagents used. However, a moderate variation in the water content may be used to regulate the viscosity of the slip and will have relatively little effect on its casting properties.

Having determined the percentages of sodium carbonate and sodium silicate which give a casting slip with the most satisfactory casting properties, the next step is to determine the minimum water content which at this degree of deflocculation will give the slip sufficiently low viscosity that it will flow through pipes of reasonable size and that the excess slip will drain cleanly from the cast in the mold. An increase in water content beyond that giving satisfactory fluidity for the operations of manufacture serves no good purpose; the excess water must be absorbed by the molds and in turn must be evaporated from the molds.

The most important properties of a casting slip do not lend themselves readily to rapid numerical measurement. The specific gravity is determined by weighing a given volume of the slip. The viscosity, or a numerical rating bearing a relation to the viscosity, can be satisfactorily determined by any one of a number of instruments, those of the flow type being commonly used. However, these two properties alone do not furnish much information concerning the action to be expected of the slip in

the mold. A slip may be prepared having any desired water content and viscosity and still be an utter failure when used in the casting shop. The rate of casting could be measured; but it is subject to a number of variables such as the character of the mold, the condition of the mold as regards water content and the number of times it has been used. The determination of the rate of casting also requires considerable time. The firmness of the cast is usually judged empirically by the feel of the cast in the mold. An instrument could be devised to measure this property, bearing in mind that a slip is unsatisfactory if the cast is soft or if it is hard, brittle and gritty when penetrated; that at the best the cast is firm but retains some plasticity and toughness. To make the determination accurate, the mold conditions would have to be standardized, as the character of the mold, its condition of moisture and the number of times it had been used would affect the results. This measurement also would be time consuming unless the determination could be made upon a thin cast, one formed in a few minutes. For the same reason it would be necessary to make the determination without removing the cast from the mold. The use of an instrument to measure firmness of cast has never come to the writer's attention. The clean-cut separation of surplus slip from the cast when a mold is drained is very important but is not readily measured. This property is usually satisfactory if the cast is firm. The strength of the cast, the rate at which it loses water and hardens in the mold and the shrinkage during this stage of stiffening are determinations requiring too much time to be used in the control of the casting slip.

Though the specific gravity and viscosity are not in themselves an index to the characteristics of a casting slip, they are useful means of factory control if the other factors influencing the properties of the slip are maintained constant. If the composition of the body does not vary and the water content of the slip is kept uniform, the viscosity becomes a measure of the degree of deflocculation of the slip and enables the operator to bring each charge of slip to a standard condition with sufficient accuracy to meet the conditions of factory operation.

In control work it is not necessary to determine the absolute

viscosity. The purpose is merely to duplicate results day after day. The quantity measured is ordinarily the time of flow of a given volume of slip through the outlet tube or orifice of a viscosimeter. The outlet may be an orifice, a short tube, a long tube, or a long tube contracted to an orifice at the end. In some cases the pressure head of the liquid varies as the instrument empties; in others the variation in pressure is largely counteracted by an immersed tube. One of the simplest viscosimeters is the Dudley viscosity pipette or an ordinary pipette of 100 cc. capacity or larger with the upper tube removed. The volume is read directly from the pipette. The Bureau of Standards type of viscosimeter for casting slips¹ has been repeatedly described and is a very satisfactory instrument. At their best casting condition a slight increase or decrease in the content of alkaline reagents produces a relatively great change in the viscosity of most casting slips, so that great accuracy in viscosimeter readings is not usually necessary. In a specific instance, increasing the alkaline reagents 3 per cent of their own weight reduced the viscosity reading 12 per cent.

Experimental

In the following study an attempt was made to hold all other factors constant while the method of preparation of the casting slip was varied. All the batches of body were weighed at one time from the same stocks of raw materials. After the body had been prepared by blunging, screening and filter-pressing, portions of it were made into casting slips by the different methods, using in each case the same proportions of body, water, sodium carbonate and sodium silicate. The time of flow of the casting slips was determined by the use of a viscosimeter of the Bureau of Standards type mentioned above. In the following the term viscosity refers to the relative time of flow of the given slip compared with water at 15° C. The instrument used delivered 200 cc. of water in 14.8 seconds. The time of flow of each slip was divided by 14.8 to obtain the quantity here designated as viscosity.

A body of the following composition was prepared:

¹ Bleining, "Use of Sodium Salts in the Purification of Clays and in the Casting Process," Bureau of Standards, *Technologic Paper* 51, p. 20.

| | |
|------------------------------|----------------------------|
| 35 Maine feldspar | 6 Georgia china clay |
| 20 Flint | 8 Florida china clay |
| 8 English china clay | 8 English ball clay |
| 10 North Carolina china clay | 5 Kentucky No. 4 ball clay |

This body is of a type commonly used for the production of vitreous earthenware and was designed to contain a number of variables. For this reason the clay content consists of English china clay, both residual and sedimentary domestic china clays and both English and domestic ball clays.

Casting slips were prepared from this body by twelve methods as given below. In methods 1 to 6, the slips were prepared by blunging in the usual double blunger. It is understood that in each case the blunger was running while being charged. In methods 7 to 12 the slips were prepared by grinding in a pebble mill. The sodium carbonate and sodium silicate were added in the form of 8 per cent solutions.

1. The water was charged into the blunger. Next the sodium carbonate and sodium silicate were added. The filter-press cakes were added to this.

2. To the water in the blunger was added the sodium carbonate. The filter-press cakes were charged into the blunger and the sodium silicate was added last.

3. To the water in the blunger were added one-half the filter-press cakes. The sodium carbonate and sodium silicate were added, and the remainder of the filter-press cakes charged into the blunger last.

4. To the water in the blunger were added one-half the filter-press cakes and then the sodium carbonate. Next the remainder of the filter-press cakes, followed by the sodium silicate.

5. To the water in the blunger was added the sodium silicate. The filter-press cakes were charged into the blunger and the sodium carbonate was added last.

6. To the water in the blunger were added one-half the filter-press cakes, then the sodium silicate, followed by the remainder of the filter-press cakes and then the sodium carbonate.

7. The water, filter-press cakes, sodium carbonate and sodium silicate were added to the pebble mill in order and ground 90 minutes.

8. The water, filter-press cakes and sodium carbonate were added to the pebble mill and ground 45 minutes. The sodium silicate was then added and the whole ground 45 minutes.

9. The water, filter-press cakes and sodium silicate were added to the pebble mill and ground 45 minutes. The sodium carbonate was then added and the whole ground 45 minutes.

10. The water, crushed dry filter-press cakes, sodium carbonate and sodium silicate were added to the pebble mill and ground 90 minutes.

11. The water, crushed dry filter-press cakes and sodium carbonate were added to the pebble mill and ground 45 minutes. The sodium silicate was then added and the whole ground 45 minutes.

12. The water, crushed dry filter-press cakes and sodium silicate were ground 45 minutes. The sodium carbonate was then added and the whole ground 45 minutes.

In preparing casting slips of the above body the amounts of anhydrous alkaline reagents used were: Sodium carbonate 0.027 per cent, and sodium silicate 0.036 per cent of the dry weight of the body. The specific gravity of the slips was 1.75, corresponding to a water content of approximately 30.5 per cent. The viscosity determinations were as follows:

| Method of preparation | Viscosity | Method of preparation | Viscosity |
|-----------------------|-----------|-----------------------|-----------|
| 1..... | 5.21 | 7..... | 4.68 |
| 2..... | 2.72 | 8..... | 3.64 |
| 3..... | 4.77 | 9..... | 5.09 |
| 4..... | 3.07 | 10..... | 10.3 |
| 5..... | 4.60 | 11..... | 4.18 |
| 6..... | 3.78 | 12..... | 8.3 |

An analysis of these figures brings out some points of interest. In methods 1 to 6 the casting slips were prepared by blunging. Of these the two having the highest viscosity were the slips to which both alkaline reagents were added at the same time, 1 and 3. The two slips ranking next in viscosity were those to which the sodium silicate was added early in the operation, while the sodium carbonate was the last ingredient added, 5 and 6. Those having the lowest viscosity were 2 and 4, to which the so-

dium carbonate was added at an early stage and the sodium silicate was added last. Of the casting slips prepared by grinding in a pebble mill three were prepared from filter-press cakes containing 21 per cent water and three from filter-press cakes that had been dried and crushed. In all cases the slips prepared from wet filter-press cakes were of lower viscosity than the slips prepared by corresponding processes, using dry clay. It is noted also that slips to which the sodium carbonate was added initially and the sodium silicate after a period of grinding were lower in viscosity than those to which the sodium silicate was added first and the sodium carbonate after a period of grinding. In the following table the members of the first column are the viscosities of slips to which the sodium carbonate was added early in the operation, while the sodium silicate was the last ingredient added. The corresponding members of the second column are the viscosities of slips prepared in the same manner except that the order in which the alkaline reagents were added is reversed.

| | | | |
|---------|------|---------|------|
| 2..... | 2.72 | 5..... | 4.60 |
| 4..... | 3.07 | 6..... | 3.78 |
| 8..... | 3.64 | 9..... | 5.07 |
| 11..... | 4.18 | 12..... | 8.3 |

A body used for casting heavy sanitary earthenware on a commercial scale was next used in preparing casting slips by the twelve methods cited above. In this case the specific gravity of the slips prepared by blunging was 1.75, while those prepared by grinding in a pebble mill were brought to a specific gravity of 1.72. It was noted in the first part of this work that slips prepared by grinding showed higher viscosity at their best casting condition than slips prepared similarly by blunging when the water content was the same in both cases. The reduction in the specific gravity of slips prepared by grinding was intended to bring both ground and blunged slips to approximately the same viscosity when they were at their best casting condition. The amounts of reagents added were 0.057 per cent sodium carbonate and 0.076 per cent sodium silicate in terms of the dry weight of the body. The viscosity determinations were as follows:

| Method of preparation | Viscosity | Method of preparation | Viscosity |
|-----------------------|-----------|-----------------------|-----------|
| 1..... | 6.26 | 7..... | 3.82 |
| 2..... | 2.95 | 8..... | 2.61 |
| 3..... | 5.82 | 9..... | 4.18 |
| 4..... | 3.50 | 10..... | 8.3 |
| 5..... | 5.07 | 11..... | 3.61 |
| 6..... | 4.45 | 12..... | 8.8 |

In general these figures confirm the results obtained by the use of the special body given above. Of the slips prepared by blunging 2 and 4 had the lowest viscosity. Five and 6 ranked next, and 1 and 3 were the most viscous. As before, the slips prepared by grinding wet filter-press cakes showed lower viscosity than those prepared by grinding dry clay. It is also noted that casting slips to which the sodium carbonate was added first and the sodium silicate later gave lower readings than the corresponding slips to which the sodium silicate was added first and the sodium carbonate later. In comparing the viscosity of the slips prepared by grinding the special body with that of the slips prepared by grinding the commercial body it must be borne in mind that in the latter case the viscosity was reduced by an increase in the water content.

The next part of the work consisted of preparing casting slips from the commercial body by the twelve methods given above and at the same time so adjusting the percentages of alkaline reagents used that all the slips had approximately the same viscosity. The specific gravity of the blunged slips was 1.75; of the slips prepared by grinding, 1.72. The viscosity of each slip was between the limits 3.65 and 3.35. The following table gives the percentages of reagents used.

| Method of preparation | Sodium carbonate per cent | Sodium silicate per cent |
|-----------------------|---------------------------|--------------------------|
| 1..... | 0.0745 | 0.099 |
| 2..... | .0545 | .0725 |
| 3..... | .0645 | .086 |
| 4..... | .0570 | .076 |
| 5..... | .0645 | .086 |
| 6..... | .0620 | .083 |
| 7..... | .0585 | .078 |
| 8..... | .0465 | .062 |
| 9..... | .0595 | .079 |
| 10..... | .0855 | .114 |
| 11..... | .057 | .076 |
| 12..... | .0805 | .1075 |

These slips were cast in plaster molds to determine whether the same body composition always gave the same result when the slip was brought to its best casting condition or whether the method of preparation influenced the casting properties of slips brought to the same viscosity. A study of the casts disclosed considerable variation in properties. The firmness of the casts was judged by the feel of the casts in the molds after the slips had been casting for 10 minutes. The slips were allowed to cast for 30 minutes when the fluid slip was drained from the casts and the comparisons made again after the casts had hardened for 10 minutes. In this way the slips were classified into the following groups: Firm cast, 2 and 4; reasonably firm cast, 1, 3, 5, 6, 8 and 9; fair, 7, 11 and 12; rather soft, 10. This method of measuring firmness does not permit of great accuracy so no comparison was made between members of the same group. Of the slips prepared by blunging those with the lowest content of alkaline reagents gave the firmest casts; the methods of preparation requiring greater amounts of sodium salts to bring the slips to their best casting condition gave slips which did not cast so firm. With reference to slips prepared by grinding this relation did not hold rigidly though method 10, requiring the greatest addition of alkaline reagents, gave the softest cast.

Discussion of Results

In general, firmness of cast is a very desirable property in the casting process and this fact recommends certain methods of preparation above others. Other factors may, however, modify the choice. For example, if the cast has the property of hardening rapidly in the mold after draining this property may overcome the effects of the softness and flabbiness of the original cast. The writer has observed a casting slip used in the manufacture of sanitary earthenware which gave a soft and apparently inferior cast at first but after draining the cast hardened rapidly in the mold and gave very satisfactory results.

Aside from the fact that blunged slips with the lowest content of alkaline reagents gave the firmest casts, another important consideration would recommend these methods of slip preparation in certain cases. In casting heavy ware using a slip that

requires a considerable addition of sodium salts to bring it to its best casting condition it sometimes happens that the high content of soluble material in the slip has a number of annoying effects. The water absorbed by the mold carries sodium salts in solution; when the water is evaporated from the mold the soluble salts are deposited as a frost-like growth or they may form a shell on the face or back of the mold. After a time this surface shell becomes comparatively impervious and hinders subsequent absorption by the mold and evaporation of water from the mold. Sodium salts are in solution also in the water remaining in the ware, when it is removed from the mold. As the piece dries these salts separate out near the surface of the ware and often appear as a brownish scurf, especially noticeable at sharp corners and edges where the evaporation is greatest. The concentration of alkali near the surface renders that portion more fusible than the body of the ware, and when the ware is fired surface vitrification results. In dipping the ware the glaze may not adhere satisfactorily to this glossy surface. In extreme cases the surface is so fusible that blistering occurs in the biscuit fire. The extent to which these undesirable conditions occur depends principally on the concentration of soluble salts in the casting slip; and if by changing the method of preparing the slip the content of alkaline reagents can be reduced, a simple solution is offered to the problem of eliminating or diminishing these difficulties of the casting process.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

A PRACTICAL TEST FOR THE RESISTANCE OF OPTICAL GLASS TO WEATHERING¹

By F. R. V. BICHOWSKY

Early in the campaign to increase the production and improve the quality of the optical glass needed for war purposes, doubts were felt as to the stability toward weather of certain of the glasses developed.

Previous to the summer of 1917, when the Geophysical Laboratory began its optical glass work, there appears to have been no attempt made by the manufacturers of optical glass in the United States to test the weather stability of their glasses. They were content to assume that the glasses, modeled after European formulas, would be at least as satisfactory in their resistance to weather as their European counterparts. The Frankford Arsenal, however, had for several years made tests for weather resistance on the glass submitted for military purposes. Three methods were developed there. In the first the glass was spotted with a 1 per cent solution of acetic acid which was allowed to evaporate in place. This test, which is said to give effects "similar to the effect of perspiration," apparently is not very sensitive, as "reddish blue spots" and "faint corrosion of the edges" were recorded for only one glass, Crown No. 1, 605, Melt 5772. Tests 2 and 3 consisted in the exposure of the glasses to 1 per cent acetic acid and 1 per cent glucose solutions for varying lengths of time. These tests, which are said to be "similar in effect to perspiration" and "to exposure to a warm climate such as the Philippines," give somewhat ambiguous results, at least in my experience. Moreover, they take too much time for routine factory testing.

It was, therefore, desired to extend and supplement these tests by a series of practical tests which could be carried out easily and quickly by the work's chemist, which would not depend too

¹ Presented before the Glass Division of the American Ceramic Society, February 24, 1920.

much on the judgment of the worker, and which would be varied enough to give some assurance that no essential peculiarity in the stability of the glass towards varying climatic conditions could be overlooked.

The ideal thing, of course, would have been to expose a carefully graded series of glasses to different and well-controlled climatic conditions for long periods of time, following somewhat the procedure of Zschimmer.¹ This was entirely out of the question in our case, since our need was for immediate data for war purposes. It must be remarked, though, that any ultimate correlation made between the results of artificial tests for the corrosion of glass by different reagents (such as those given below) and the actual weather resistance of the glass to real climatic conditions must depend on some such investigation. All that could be done here was to pick out tests sufficiently varied so that it could be reasonably hoped that whatever might be the peculiar susceptibilities to weathering of the glasses in question, they would be detected by some of the tests employed.

Optical glass is not readily obtained in the form of blown articles, nor can it be blown readily in the laboratory. It was thus impracticable to test the glasses by the methods used to test the stability of chemical glass.² The optical glass tested usually came in the form of pressed or polished plates from 1 to 2 cm. thick, these often being samples which had been discarded in the factory inspection on account of fine striae. As would be expected, experiment shows no marked effect on the weathering quality of the glass due to fine and almost imperceptible striae present in the optical glass tested.³

The first test that suggested itself was the well-known "surface alkali" test described by Mylius.⁴ This test depends on the

¹ E. Zschimmer, *Chem. Zeitg.*, **25**, 730-732 (1901).

² Such, for example, as those used by Walker and Smither, *Jour. Ind. Eng. Chem.*, **9**, 1090-1092 (1917).

³ Blown ware often shows marked differences of resistance to "weathering" by hot water, at least along the combined striae and molding lines of the article. (See the following paper.) But these "striae" are of a very different magnitude from those found in optical glass.

⁴ F. Mylius, *Z. anorg. Chem.*, **55**, 233-260 (1907); **67**, 200-224 (1910); *Silikat-Zeitschrift*, **1**, 2-5, 25-28, 45-48 (1913).

fact that when a freshly broken surface of glass is placed for a given period in a dilute ether solution of iodeosin, $C_{20}H_{14}O_5$, a certain amount of the ether-insoluble alkali salt of this acid, depending, among other things, on the alkalinity of the glass, is precipitated on this surface. The excess free iodeosin can easily be washed off with a little ether, and the amount of iodeosin in the form of its alkali salt can be found by washing off the surface with a little water, in which the alkali salt is soluble, and determining colorimetrically the total amount of indication in this extract. The details of the procedure differ but little from those given by Mylius. The following solutions are needed:

Solution A.—0.53 gram of sodium iodeosin, *i. e.*, erythrosin B or anilin red (caution: several different dye-stuffs are sold in the United States under these trade names) is dissolved in a 2-liter separatory funnel in 30 cc. of H_2O . To this solution is added 15 cc. of a one-tenth normal solution of sulfuric acid. The free iodeosin will be precipitated by this procedure in large orange-red flakes. The mixture is then shaken vigorously with a liter of well-washed ether until the free iodeosin is entirely dissolved. (The acid must be added before the ether, otherwise it is difficult to make the dye-stuff dissolve.) The aqueous layer is removed and the ether solution washed three times with a little water (about 30 cc.). The water from the last washing must be distinctly red.

Solution B.—Solution A is sensitive to light and slowly becomes acid through oxidation. To maintain the solution as sensitive as possible it is kept in a stoppered bottle of brown glass, in contact with 30 cc. or so of a 1 per cent solution of sodium iodeosin. This bottle must be kept full (to keep out air) by adding more of solution A every time solution B is used. Mylius recommends keeping some fragments of soda glass or some glass beads in the bottle to prevent the solution becoming acid, but with ordinary American glass bottles this is unnecessary.

Solution D.—0.01053 gram of pure sodium iodeosin is dissolved in a liter of water. This solution, which should be kept in the dark, contains 0.01 mg. of free iodeosin per cc., and is used as a

standard solution. It is comparatively stable and can be kept for several months in a dark bottle without change.

Besides these solutions, neutral water saturated with ether will be needed. Ether of the grade used for anesthesia, which has been washed a couple of times with fresh distilled water, will serve.

The procedure recommended is as follows: The plates of optical glass are washed with ether, alcohol and water, and dried on a soft cloth. They are then scratched with a diamond so as to give, when cut, several square centimeters of fresh surface. A little of solution B is placed in a shallow dish so as to make a pool half a centimeter deep. The plate of glass is then broken along the diamond scratch with a quick light tap of a wedge-shaped hammer, the glass being held scratched side down in the palm of the hand or supported between two pieces of cork. The freshly broken surface is then put face down in the ether solution and gently moved around for one minute. The pieces are then quickly removed, rinsed with the prepared ether and allowed to dry. The excess indicator on the old surfaces of the glass and in the neighborhood of any imperfections on the new surfaces is carefully removed with a damp cloth, pains being taken that no water gets on the new surface and that no dye is left on the old surface and especially on the rough edge where the diamond has cut. The dye on the fresh surface is then carefully washed with a few cubic centimeters of water into one of two similar small deep beakers. The color is compared with that of the standard solution D by adding solution D drop by drop from a graduated burette into the other of the two beakers until a perfect match is obtained, taking the usual precautions, as to light and volume of solution, needed in all colorimetric work. The other dyed surface of optical glass should be treated in a similar manner, the two beakers being interchanged, however. The amount of solution needed for the color should be nearly the same, and the mean value should be taken. This value, in cubic centimeters of solution D used, multiplied by 100 and divided by the estimated area of the fracture in square centimeters, gives the number of milligrams of adsorbed iodeosin per square meter. This value may be called the surface alkalinity constant of the glass in ques-

tion. As Mylius has shown, glasses can be fairly grouped into five classes on the basis of this constant, namely:

| | | Mg. per sq. m. | Example |
|----------------|---------------------------|----------------|-------------------------------|
| Class I..... | Totally insoluble glasses | 0-5 | "Quartz glass" (fused silica) |
| Class II..... | Resistance glass | 5-10 | Jena Geräte (chemical) Pyrex |
| Class III..... | Hard glass | 10-20 | Flints, best crowns |
| Class IV..... | Soft glass | 20-40 | Ordinary crowns |
| Class V..... | Poor glasses | over 40 | |

Optical glasses should all have a surface alkalinity less than 40, though it is to be noted that glasses high in lead (such as the extreme microscope flints) give high values for surface alkali¹ while they are extremely insoluble in water. This is possibly due to the formation of a lead salt of iodeosin in place of the alkali salt formed on ordinary glasses. It should also be noted that certain glasses containing barium and possibly zinc, though they give low surface alkali values, have very high solubility in acid, and are presumably only fairly stable to weather. For these reasons the results of the surface alkali test should always be interpreted in conjunction with other tests.

The further test given by Mylius, namely, the amount of indicator absorbed on glass surfaces which have been exposed to water vapor at 18 degrees for seven days, is somewhat inconvenient and uncertain, and it was felt that it was too similar in principle to the first test to have especial value.

It was at first hoped that some convenient quantitative method could be found for determining the true rate of solubility of glass in water and various other reagents. Conductivity and electromotive force methods were tried but were thought to be too difficult for routine work. Extraction of a known surface of glass with concentrated ammonia, 1:1 hydrochloric acid, and water, filtering, evaporating to dryness, and weighing the extracted alkali, was tried with fair success on nearly all the glasses employed. The glass used was cut up into small cubes, and their surface was estimated; they were then extracted for 48 hours on a

¹ Hovestadt, "Jena Glass," (transl. by J. D. and A. Everett), p. 323. London, 1902.

water bath, using fused silica or silver beakers. The extract was then concentrated to small volume, filtered, and evaporated to dryness in small platinum dishes. Filtration is necessary as the glass spalls badly, and it is difficult to separate the undissolved splinters of glass from the slush of hydrated silica which settles to the bottom of the beaker. This spalling also makes the estimation of total surface very uncertain, and the more or less colloidal state of the silica renders uncertain whether the filtered solution represents fairly the amount of alkali dissolved, or whether it represents in addition more or less of the silica. This last source of error can be overcome, of course, by acidifying the extract with HCl before evaporating to dryness, and carrying out the usual procedure for the elimination of silica. The whole method, however, is thought to be not satisfactory for routine use.

The tests finally adopted are not quantitative, and their interpretation depends somewhat on the judgment of the operator. They are, however, simple and rapid, and a little practice will make interpretation quite positive enough for the purpose. The tests consist in heating the glass to high temperatures with various solutions and noting the appearance of the surfaces, both when wet and when dry. A great many types of solutions were tried, but water, 5 per cent solution of sodium hydroxide, and 1 : 1 hydrochloric acid prove to give the most satisfactory results, and apparently nothing is to be gained by extending this list.

Steel bombs were used for the extraction with water and sodium hydroxide. The fragments of glass, half-inch cubes, which may be weighed, marked and described for identification, were introduced. The bomb was filled three-fourths full with the solution used, put quickly into a furnace kept at approximately 225°C ., and left there for 4 hours, in the case of water, and 2 hours in the case of 5 per cent sodium hydroxide solution. A standard sample of glass was always used in each bomb. It makes very little difference what the standard sample is. I used Jena thermometer glass 59". The test with 1 : 1 hydrochloric acid was made in sealed tubes of Jena combustion glass at a temperature of 175°C . for 6 hours.

The appearance of different glasses under these tests can be

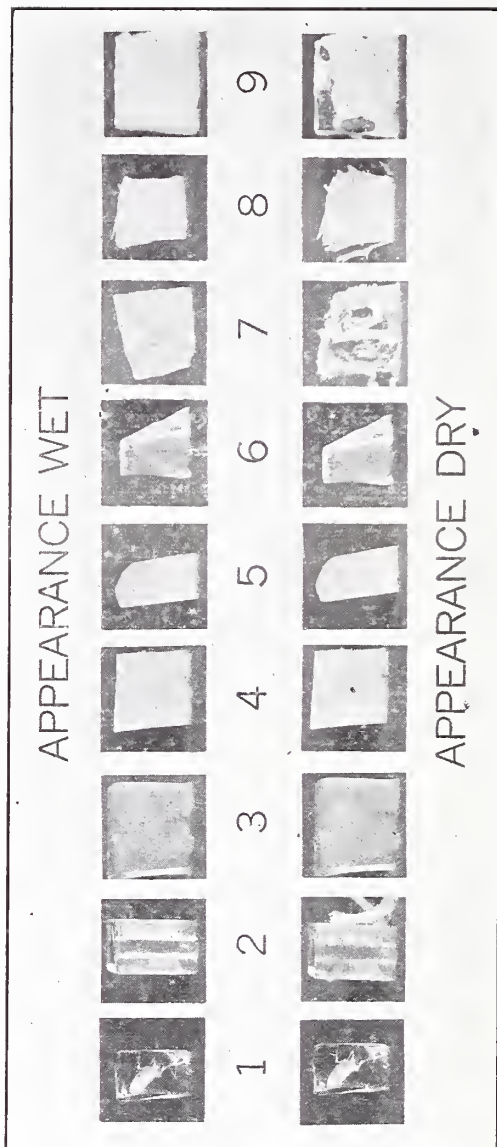


FIG. 1.

judged somewhat from the photographs in figure 1. Under these conditions glasses can be graded rather sharply as follows:

| Grade | Appearance wet | Appearance dry |
|-------|---------------------------------------|--|
| 9 | Thick slushy film | Film more than 1.5 mm. ($\frac{1}{16}$ inch) thick when dry |
| 8 | Thick film | Flakes off when dry |
| 7 | Deep etching in scratches and corners | Thin film, flakes off when dry |
| 6 | Deep etching in scratches and corners | Thin film, does not flake off when dry |
| 5 | Opalescent film | Deeply etched |
| 4 | Opalescent film | Not etched |
| 3 | Film | Film |
| 2 | Clear | Film |
| 1 | Clear | Clear |

It is also possible to keep track of the loss of weight, but with glass samples which have sharp edges the loss due to spalling and chipping renders these results less positive than the appearance of the test pieces. Typical results obtained by these tests are given in table 1. Column 1 gives the glass tested, column 2

TABLE 1.—RESULTS OF WEATHERING TESTS ON OPTICAL GLASSES BY VARIOUS METHODS

| Glass | Surface alkali | Solubility in water, Mg. | Grade by appearance | | |
|-----------------------|----------------|--------------------------|---------------------|------|-----|
| | | | H ₂ O | NaOH | HCl |
| BL. 100..... | 44 | 130 | 6 | 7 | 2 |
| BL. 500..... | 15 | 57 | 5 | 8 | 3 |
| BL. 3000..... | 13 | 39 | 4 | 3 | 1 |
| BL. 3700..... | 16 | (170)? | 1 | 2 | 1 |
| | | 54 | | | |
| BL. 700..... | 25 | 70 | 2 | 4 | 9 |
| PPG. A..... | 24 | (420)? | 2 | 8 | 1 |
| PPG. C..... | 33 | 86 | 4 | 2 | 2 |
| PPG. E..... | 50 | 140 | 5 | 9 | 3 |
| PPG. H..... | 18 | 51 | 3 | 5 | 1 |
| Microscope flint..... | 39 | .. | 1 | 2 | 1 |

the results for the surface alkali test, column 3 loss of weight of centimeter cube in distilled water in milligrams per test, and columns 4, 5 and 6 the grade in accordance with appearance.

It will be noted that there is considerable difference in the order of stability that would be assigned according to the different

tests. Thus glass BL. 700 is actually so soluble in hydrochloric acid that crystals of BaCl_2 separated out of the acid in 6 hours heating. This glass loses one-tenth of its weight in boiling 1 : 1 hydrochloric acid in 72 hours. On the other hand, according to all other tests, it is a fairly good glass. Just what the weather resistance of such a glass would be it is hard to say. However, it is certain that if we depended on any single one of these tests alone, our estimate of the probable weather resistance of the glass, though more *definite* than the result of the group of tests taken together, would very likely be wrong. Probably the safest thing to say is that glasses such as BL. 100 and PPG. E, which are poor according to *all* tests, are likely to have poor weather resistance, and those that are satisfactory according to all tests are likely to be satisfactory under actual weather conditions. Glasses which are intermediate in quality or show great variation under the different tests should be considered with suspicion and means should be taken to obtain field data as to their actual weathering stability. With such a body of data, no doubt, correlation factors could be obtained between the results of the artificial tests and actual weathering resistance.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON
July, 1919

DISCUSSION

MR. GEORGE W. MOREY.—We should be very cautious in giving weight to stability tests made under such extreme temperature conditions as 225°C. , and with such violent reagents as 1 : 1 HCl and 5 per cent NaOH. While the results of such tests are interesting, it is up to those presenting such tests to the manufacturer to show that they have some bearing on the actual behavior of the glasses under the conditions of use. BL. 700, a glass which has shown itself, in actual use, to be fairly resistant, appears decidedly inferior when treated with 1 : 1 HCl at 225°C. ; not very surprising when we consider the conditions of the experiment.

The phenomenon is one of rate of decomposition. Superimposed on the purely accelerating effect of temperature we undoubtedly have other effects which profoundly affect the rate,

and hence the magnitude, of the effect we measure. The only silicate systems whose actual equilibrium relations with water are known, the alkali silicates, show a profound difference in behavior at 200° and at room temperature; not only differences in equilibrium relations but also in the condition of the products of decomposition, whether passing into true solution or into an unstable peptized state or even remaining as translucent to transparent layers, apparently unaltered in appearance, but with alkali or other dispersed material replaced by water. Similar effects were observed by Van Bemmelen with SiO_2 gels, and by the author with alkali silicate crystals.

To be of real value in factory control, the method must be competent not merely to show the difference between a borosilicate crown and a barium flint, but furthermore to show the effect of changes in batch composition in the case of a given glass. If a certain glass is not as stable as it should be, and we change the $\text{Na}_2\text{O} : \text{K}_2\text{O}$ ratio, or add alumina, have we made a step in the right direction? The manufacturer wants a method which will answer these practical questions, and answer them in an unequivocal manner. If the method takes a week to carry out, instead of an hour, all right, as long as it gives results.

It has always been customary to use a freshly broken surface for weathering tests; this is proper. But the surfaces with which we are really concerned are always polished surfaces; an investigation of the effect of polishing on weathering is desirable. If there is the marked difference in properties between the polished surface and the interior, inferred by French from his experiments on polish; if the properties of the β -layer are so markedly different from those of the α -layer in other ways, it would surely differ greatly in weathering. On the other hand if the theories of the chemical theory of polishing are correct, in this case also the polished surface should differ from the interior, and, moreover, surfaces equally polished should be different when different polishing mediums are used. These questions need investigation.

SPENCER LENS CO.
OPTICAL GLASS PLANT
HAMBURG, N. Y.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

MR. W. F. BROWN.—Dr. Bichowsky's work to develop simple and rapid tests for grading optical glass as regards its ability to resist weathering calls to mind a problem once submitted to the writer by a manufacturer of glass other than optical. It was required to give within as short a time as possible a report as to which of several glasses would best resist weathering action while in the warehouse, the ware being packed with hay or straw in wood boxes.¹

Chemical weathering tests described in the literature were decided not to be positive enough to apply directly to the case in question, but they indicated what course to follow with only a partially equipped laboratory and no autoclave available. It was desirable to have test pieces large enough to show why the particular glass recommended was more resistant than the others.

It is generally known that the reason glass deteriorates in storage is because it "sweats." Even in a dry warehouse, temperature and humidity changes cause closely packed glass to become damp or even wet. Ordinary soda glasses "bloom" after a short storage period, and under more severe conditions and longer storage the glass surface may become so iridescent or etched that its deterioration affects quality appreciably. When too badly "bloomed," ordinary methods of washing will not restore the surface.

A little experimenting showed that in every case the "sweat" from packed glass was alkaline, the alkalinity apparently increasing in direct proportion to depth of surface corrosion. Following results to be expected from the usual methods for testing stability of chemical glassware, it was noticed that a glass surface given an artificial alkalinity, as by dipping into a dilute solution of sodium hydroxide, and kept dry, would not alter its appearance, while the same glass so tested and put where it would "sweat" showed signs of surface deterioration within a week.

A number of boxes representative of the several glasses to be

¹No attempt has been made in this discussion to give references, and it is realized that a much better method for determining tests was published in the August, 1919 number of the *Journal Society of Glass Technology*. The particular work, however, to which I had reference was done quite a while before the above article appeared.

tested were then taken directly after manufacture and packing, and buried in fresh horse manure, not exposed to outdoor weather. The pile had been well mixed, and care was taken to have each box surrounded with about equally thick layers of dung. The pile was sprinkled with water every few days, but was at no time wet enough to make wet the boxes or hay packing. All the moisture which collected on the glass was due to "sweating." Temperature within the pile at first was 118° F. and gradually diminished to 95° F. within 30 days. At the end of the 30 days, when some of the glass was taken out of pack, it was easily seen which glass was most resistant to weathering action, at least under actual storage conditions.

An analysis of the glass tested led to the belief that it was much more stable than ordinary bottle glass, but not so stable as good chemical ware.

It may be asked if the humus gases aided surface corrosion. It is not believed they caused any effect. A number of pieces of glass were put into a water-jacketed copper oven kept at 180° F., and into which were passed streams of carbon dioxide and ammonia. It was difficult to control the humidity of the oven atmosphere, and in the rough experiments so conducted the glass could not be made to "sweat" as it did in the manure pile, and no definite results were obtained from the few oven tests made.

From the comparative results obtained by burying packed glass in manure, which method in reality gave a crude combined thermostat and humidostat, it is suggested that if work be done as proposed by Dr. Bichowsky to compare actual long-period weather resistance of glass with results produced by his practical laboratory tests, it would be interesting to correlate further the relation between artificial "sweating" for short periods under known and reproducible conditions with the actual long period weathering.

MR. A. J. WALCOTT.—In connection with the "weathering" action of glass, especially optical glass, the writer has been especially interested, not only in the causes but also in determining the nature and composition of the resulting deposit. It has already been reported by a number of investigators that the

result of one form of weathering is a deposit of small globules and a pitted condition of the surface. A careful microscopic study of a large number of specimens of glass, subjected to weathering action, has brought the following information:

Each pit is filled with a globule or bead of a stiff jelly-like substance, soluble in water. The substance has been found to possess the property of double refraction, giving an interference color of low order. In a few cases a faint biaxial interference figure has been observed. The index of refraction has as yet not been determined but has been found to be lower than 1.6. Flame tests and blowpipe tests have led the writer to believe that, in at least some cases, the composition of these "beads" is potassium silicate.¹

Further experimental work seems well worth while and will undoubtedly lead to interesting and valuable information.

¹This work was done at the Bausch & Lomb Optical Co., and with glass having an index of refraction of 1.616.

NOTE ON THE MECHANICS OF THE "WEATHERING" OF GLASS¹

BY F. K. v. BICHOWSKY

It has been noted by a number of workers² that water is taken up in considerable amount by fresh glass surfaces. Thus glass which has been soaked in water for some time will lose considerable weight on drying to 150°. Schott notes, for instance, a glass which had adsorbed as much as 10.7 milligrams of water per square decimeter of surface. Apparently the mechanism of this ad- or absorption differs with different kinds of glasses, but in general it seems to consist of the following stages:

1. True adsorption of water on the surface.
2. Diffusion or "solution" of the adsorbed water molecules into the body of the glass.
3. Reaction of the dissolved and adsorbed water with the glass, forming a surface film of more or less thickness and of a character depending on the composition of the glass.
4. Soaking up by this film of considerable amounts of water with consequent further reaction.
5. Extraction of the soluble salts (mostly the alkaline carbonates and hydroxides) from this surface film.
6. Solution of the silica skeleton film in the strongly alkaline solution formed.

Of course, these changes are not absolutely definite. There is a certain amount of overlapping. Still it is assumed they are approximately definite.

Now, if a glass has reached stage 1 and is heated, the glass will lose weight by the amount of water adsorbed, but there

¹ Presented before the Glass Division of the American Ceramic Society, February 24, 1920.

² O. Schott, *Zts. Instrumentenkunde*, **9**, 86-90 (1880); F. Foerster, *Ber. deutsch. Chem. Ges.*, **26**, 2915-2922 (1893); *Zts. anal. Chem.*, **33**, 299-322, 322-335 (1893); F. Mylius and E. Groschuff, *Zts. anorg. Chem.*, **55**, 101-118 (1907).

will be no change in character of the surface no matter how rapidly it is heated. Under the time and temperature conditions of his experiment, Schott's Jena Glass 15''' had reached only this stage. My glass¹ BL. 100 was still in this stage after 20 minutes heating with water at 225°. At 30 minutes it had reached stage 2.

If a glass has reached stage 2 the character of the resultant surface will depend, given equal quantities of water absorbed, on the rate of drying and on the mechanical properties of the glass, such as its hardness, density and tensile strength. On quick heating the glass surface will show a fine pattern of cracks (sometimes microscopic), coarse isolated cracks, splinters, or chips. The surface, however, will show no chemical change. Under the conditions of Schott's experiments most of his glasses reached this stage. My glass BL. 100 reached this stage in 30 minutes, and stage 3 in 45 minutes.

Glasses which have reached stage 3 will usually, but not always, show signs of chemical action, such as a translucent skin, even without further heating. With certain glasses, usually potash glasses (according to Foerster), the chemically different surface layer may still be transparent or semi-transparent, and it would take a careful microscopic examination or determination of the refractive index to determine whether the glass had been acted on chemically. What takes place when a glass which has reached stage 3 is heated is very complicated, depending on both the chemical and mechanical properties of the glass. As has been said, some potash glasses give an amorphous transparent skin, which may be considered opaline silica bound together with potassium silicate. This skin when dehydrated becomes opalescent and semi-transparent, and chips off, sometimes with large surface flakes and grains; and sometimes, as a result of very slow alternate wetting and drying, especially in glasses containing a large amount of lime, it comes off in the form of bubbles or

¹ See preceding article. Besides water, other substances are adsorbed and react on glass surfaces, affecting markedly their reflecting power. H. D. Taylor, "Adjustment and Testing of Telescope Objectives," York, England, 1894; F. Kollmorgen, *Trans. Illum. Eng. Soc.*, 11, Pt. I, 222-234 (1916). Also unpublished experiments by F. E. Wright and J. B. Ferguson.

films which separate rather sharply from the untouched glass below. Often these bubbles or films show both the Newton and opal colors and strongly resemble Roman glass. Thus the glass bottle illustrated in figure 1 (a Greiner and Friedrichs "Re-

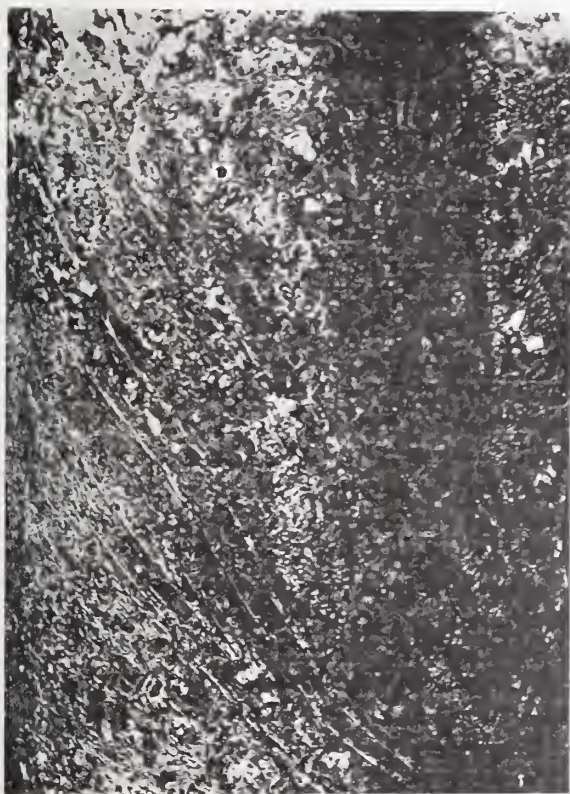


FIG. 1.

sistenz" bottle which had been exposed to hot water and to steam alternately for more than three months) shows brilliant Roman color effects. Here the hydrated and more or less plastic silicate film has separated from the glass underneath in the form of innumerable bubbles of unusually large size. The illustration is magnified 4 diameters. On the other hand, certain soda

glasses, when heated after reaching stage 3, flake off hard particles like sand, or form deep cracks in an enamel-like surface, and show other peculiarities which can readily be accounted for on the basis of this theory.

The appearance and behavior, on heating, of glasses in stages 4 and 5 are, of course, obvious. Stage 4 was reached in glass BL. 100 in 60 minutes. The time needed to reach stage 5 has no significance.

The theory outlined here for weathering with water is probably applicable to all weathering of glass, but the weathering due to other agents has not come under the author's experience.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON
July, 1919

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

A SATISFACTORY METHOD OF USING BARIUM HYDRATE IN TERRA COTTA BODIES

BY M. E. GATES

The usual method of using barium carbonate in a terra cotta body is to calculate the amount of barium carbonate necessary to take care of soluble salts in the body, and, using this as a basis, to add 100 per cent extra of the barium carbonate to take care of variations in the amount of soluble salts.

In the use of barium hydrate this same rule can be applied, if it is thought advisable. By this we mean that we have never experienced any difficulty with barium hydrate when used to the extent of two or three times the ordinary amount. The reason for this seems to be that:

1. Barium hydrate is very nearly insoluble in water. One-half of 1 per cent barium hydrate to clay, if added to the total mixing water, would mean only a solution of about 2 per cent barium hydrate to water by weight. This would be the proportion with the ordinary terra cotta body of 66 per cent clay and 33 per cent grog. Using the barium hydrate under these conditions we find it to be too insoluble for uniform results, *i. e.*, the barium hydrate if mixed in the free water tank would result in the solution coming from the tank not being uniform.

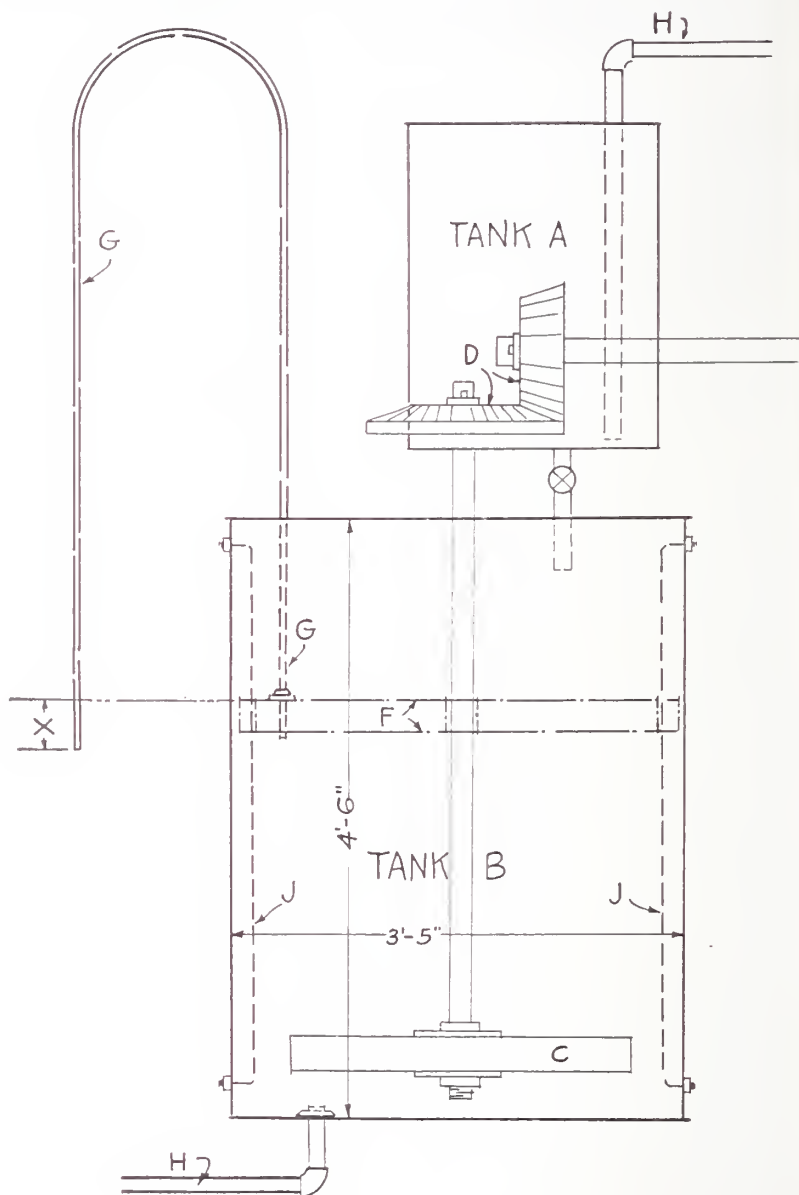
2. If it should come to the surface of the terra cotta it will immediately be changed to barium carbonate, due to the action of the air upon it. There are instances where the barium hydrate has come to the surface, and left a white scum, mostly on the projecting corners. This, however, does not seem to cause any bad effect.

The advantages of using barium hydrate are:

1. That it is not necessary to add this extra proportion of barium hydrate to do away with the ordinary scumming which is encountered with soluble salts, due to the fact that it is more soluble than barium carbonate and consequently comes more easily into contact with the salts. Therefore, it is more economical.

2. Barium hydrate is so nearly insoluble in the per cent (about 14 per cent) solution and temperature of mixture we use that we

had to devise means for keeping it in solution until we could get it into the body mix.



Our method of applying barium hydrate is the result of two or three years of study. The machine we have devised is shown on the accompanying drawing, in which "A" is the preliminary mixing tank for dissolving the barium hydrate, which later is drawn into tank "B" through a valve and pipe. In "B" we have a paddle wheel "C" driven by the gears "D," this paddle revolving at the rate of nine revolutions per minute. The tank "B" is 3 feet 5 inches in diameter, 4 feet 6 inches high. The paddle wheel "C" is revolved at all times during the use of the mixing machinery, so as to keep the solution as near constant as possible. We have a steam pipe "H" connected to the tank "B" to warm the mixture in case it becomes too cold. It is necessary to keep this above a certain temperature, depending upon your mixture, or the material will crystallize. For feeding from the tank "B" to the mixing machine we have a syphon pipe "G" supported by the float "F." The outside lower end of this pipe "G" extends below the level of the liquid in the tank "B" by the distance "X." Changing the difference in the dimension "X," of course, changes the amount of flow per minute. The pipe "G" is made so that it can be picked up from the float "F." This is for the purpose of being able to keep it clean. If it is left in the mix the barium hydrate will crystallize in it, and, therefore, stop the flow, and consequently change the value of the dimension "X" of the syphon. The float "F" must, of course, move freely up and down with the level of the liquid in "B," which is accomplished by guide rods "J."

This system has been in use for five years, with very few changes. It gives excellent results, without any technical supervision, the clay-mixing foreman being able to attend the machine himself, and to check the quantity of barium hydrate he is putting into his mix—adding so many pounds of barium hydrate every inch he fills his tank. He simply establishes a rule that every so many hours or minutes run, the level in the tank "B" should change a corresponding amount.

THE AMERICAN TERRA COTTA AND CERAMIC COMPANY
TERRA COTTA, ILLINOIS
January, 1920

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

TITANIUM ENAMELS

BY ROBERT D. LANDRUM AND LEON J. FROST

Titanium oxide is a ceramic material which has received little, if any, mention in American enamel literature. It is used by the enameler as rutile, in which form it contains iron oxide (Fe_2O_3) as the principle impurity. Rutile has a brown color although the pure oxide is nearly white.

In Vol. 42 (p. 598) of *Sprechsaal*, Vondracek gives the following under the heading, "Titanium as an Opacity Producing Material."

"An opacifying material standing very near to oxide of tin is oxide of titanium. The best known source of this material is rutile, which consists essentially of titanium oxide (TiO_2) with iron and some silica and alumina as impurities. When used in a glass or enamel there is a great tendency for a yellowish color to develop even though only a small per cent of the material may be used. This coloring action is evidently caused primarily by the impurities, iron and possibly chromium, but secondarily by a reduction of the TiO_2 to a lower oxide of a yellow color by any reducing materials or gases in the mixture.

"Leuch has patented the process of partially replacing the silica in glasses by titania and if this be free from impurities and melted in an oxidizing atmosphere a colorless (*i. e.*, not opaque) glass will result. Such a glass has the following properties:

- "1. It melts at a lower temperature than those with all silica.
- "2. It withstands the action of acid vapor much better, even though but little titania is present. (One molecule of TiO_2 to two molecules of SiO_2 is very resistant to acids.)

The addition of titania to a glass, therefore, seems to combine the good properties of a high silica glass and a low silica glass containing boric acid, lead, or fluorine, for such a glass withstands the action of acids as well as the former and melts and flows as easily as the latter. The specific gravity of such a glass is much higher and its refractive power is also greater (they are very glossy).

Opacity is caused by the addition of larger proportions of titania, and this point is of special interest to enamelers. Artificial, technically pure, TiO_2 becomes insoluble in the enamel upon heating to redness and cooling slowly so as to allow an invisible crystallization to take place, thereby developing opacity. When used in this connection it is a good substitute for tin oxide.

Philipp Eyer in his book "Emaile Wissenschaft" confirms most of the above points and emphasizes especially the detrimental discoloration. Drs. Hillringhaus and Heilman, however, in their patent 207,001 (German) claim to get away from the yellow color by the addition of cobalt oxide. The patent reads in part: "Research has proven that by the addition of cobalt oxide to a titanium enamel it is possible to prevent this yellow cast and to obtain a nearly white enamel. Previous literature has held that titanium oxide gives a yellow-green when used in combination with cobalt oxide. As a result of this fact no attempt has been made in the enamel industry to secure the complimentary blue color from this source, in spite of the great need of a means of masking the yellow. Therefore, the application of TiO_2 has been neglected and the expensive SnO_2 has continued in use. The researches which lead to the above discoveries have established the falsity of the previous statements."

"In applying the above principle a small amount of cobalt oxide is added either to the TiO_2 itself or to the enamel containing it previous to smelting; or, a bright blue flux may be prepared and this used in the enamel mix or added to the titanium itself previous to the mixing.

"By means of this procedure it is possible to displace the expensive and less acid resisting tin glaze with the cheaper and more durable titanium enamel."

A number of titanium enamels have been made for the purpose of confirming some of the above statements and in the hope of throwing some light on the practical working compositions containing this material.

The first series, A, figure 1, consists of five enamels (really glasses in character) published by Vondracek. In as far as was possible with the enamels under consideration, the same methods of manufacture, testing and reporting used by one of the writers

| INDEX | GRAPHIC FORMULA | MILLING TIME | MILLING | FRIT | OPACITY | ACID LOSS | HEATING TESTS | IMPACT | GLOSS | REMARKS |
|-------|---|---------------------------------|--|-----------------------------------|--|--------------------------|---------------------|---------------------|-------|---|
| 1 | $\left. \begin{array}{l} .488 \text{ Na}_2\text{O} \\ .066 \text{ K}_2\text{O} \\ .446 \text{ CaO} \end{array} \right\} .445 \left\{ \begin{array}{l} 1263 \text{ SiO}_2 \\ \text{TiO}_2 \end{array} \right.$ | 20 MIN 34.26% 23.40% 20 | 6% SnO ₂ 7% Clay 1/4% MgO | Yellow Tint Clear Heavy | Very Poor 17% 6.05% | None (No effect) | Very Excl. 16 | Good Excl. | Excl. | This glaze is exceptionally durable |
| 2 | $\left. \begin{array}{l} .507 \text{ Na}_2\text{O} \\ .030 \text{ K}_2\text{O} \\ .463 \text{ CaO} \end{array} \right\} .463 \left\{ \begin{array}{l} 1233 \text{ SiO}_2 \\ \text{TiO}_2 \end{array} \right.$ | 20 MIN 34.08% 24.75% 21 | 10% Clay 1/2% MgO | Yellow Green Clear Heavy | Very Poor 34% 2.77% | None (no effect) | Very Good 17 | Good Excl. | Excl. | Similar to #1 |
| 3 | $\left. \begin{array}{l} .488 \text{ Na}_2\text{O} \\ .066 \text{ K}_2\text{O} \\ .446 \text{ CaO} \end{array} \right\} .446 \left\{ \begin{array}{l} 1.338 \\ \text{SiO}_2 \end{array} \right.$ | 21 MIN 35.57% 22.92% 19 | 10% Clay 1/2% MgO | Pale Green Clear Heavy | Very Poor 77% 5.93% | None (No effect) | Very Good 15 | Very Good 81% | Good | Similar to #1 & 2 |
| 4 | $\left. \begin{array}{l} .726 \text{ Na}_2\text{O} \\ .055 \text{ K}_2\text{O} \\ .219 \text{ CaO} \end{array} \right\} .166 \left\{ \begin{array}{l} 663 \text{ SiO}_2 \\ 588 \text{ B}_2\text{O}_3 \end{array} \right.$ | 15 MIN 16.88% 32.63% 9 | 20% Clay 1% MgO | Pale Green Soft | Not 29% 4.67% 30.90% 5.63% | Not Comparable | | Good | Good | Of no value as an enamel |
| 5 | $\left. \begin{array}{l} .612 \text{ Na}_2\text{O} \\ .092 \text{ K}_2\text{O} \\ .246 \text{ CaO} \end{array} \right\} .558 \left\{ \begin{array}{l} 280 \text{ SiO}_2 \\ \text{TiO}_2 \\ 664 \text{ B}_2\text{O}_3 \end{array} \right.$ | 12 MIN 6.54% 25.26% 11.53% 7 | 20% Clay 1% MgO | Green Soft | Good Unevenly Tested (copied) | Not 23% 32.05% 17.39% | Fair | Good Good | Good | Exceptional fire resistance and long burning range. |
| | | | | | | | | | | |

→ RUTILE
→ BORACON
→ SALT PETER
→ CALCITE
→ SODA
→ QUARTZ

| GRAPHIC FORMULA | APPEARANCE TIME | FRIT | MILLING | OPACITY | ACID LOSS | HEATING TESTS | IMPACT | GLOSS | REMARKS |
|---|--------------------|--|--|---------------|--------------|------------------|--------------|--------------|--|
| 6 $\begin{matrix} .489\text{Na}_2\text{O} \\ .066\text{K}_2\text{O} \\ .445\text{CaO} \end{matrix} \left\{ \begin{matrix} .445 \\ .1263\text{SiO}_2 \\ .066\text{Sb}_2\text{O}_5 \\ .445\text{TiO}_2 \end{matrix} \right.$ | 25 MIN | Ivory Very Opaque Heavy | 10% Clay 1/2% MgO | Quite Good | None | Very Good | Very Good | Excl. | Difficult to apply 18.6% 10.57% |
| 7 $\begin{matrix} .487\text{Na}_2\text{O} \\ .066\text{K}_2\text{O} \\ .447\text{CaO} \end{matrix} \left\{ \begin{matrix} .145 \\ .1267\text{SiO}_2 \\ .447\text{TiO}_2 \\ .1320\text{F}_2 \end{matrix} \right.$ | 25 MIN | Ivory Very Opaque | 6% SnO ₂ 7% Clay 1/2% MgO | Very Good | .0017 Gr. | Poor | Good | Good | The failure in heating test caused by corrosion of ground coat. |
| 8 $\begin{matrix} .742\text{Na}_2\text{O} \\ .078\text{K}_2\text{O} \\ .180\text{CaO} \end{matrix} \left\{ \begin{matrix} .300 \\ .2444\text{SiO}_2 \\ .371\text{TiO}_2 \\ .1203\text{Al}_2\text{O}_3 \end{matrix} \right.$ | 18 MIN | Yellow Brown Med. Uneven Opacity | 6% SnO ₂ 7% Clay 1/2% MgO | Good | None | Very Good | Very Good | Very Good | This enamel wrinkled well |
| 9 $\begin{matrix} .672\text{Na}_2\text{O} \\ .142\text{K}_2\text{O} \\ .186\text{CaO} \end{matrix} \left\{ \begin{matrix} .310 \\ .2521\text{SiO}_2 \\ .398\text{TiO}_2 \\ .1203\text{Al}_2\text{O}_3 \end{matrix} \right.$ | 16 MIN | Creamy White Med. Opacity | 6% SnO ₂ 7% Clay 1/2% MgO | Good | .0006 gr. | Good | Poor | Very Good | Failure of impact test due to defective ground Enamel worked well. |
| 10 $\begin{matrix} .536\text{Na}_2\text{O} \\ .146\text{K}_2\text{O} \\ .318\text{CaO} \end{matrix} \left\{ \begin{matrix} .332 \\ .2710\text{SiO}_2 \\ .152\text{B}_2\text{O}_3 \\ .270\text{TiO}_2 \\ .1067\text{F}_2 \end{matrix} \right.$ | 40 MIN | Creamy White Good Opacity | 6% SnO ₂ 7% Clay 1/2% MgO | Quite Good | .0024 gr. | Excl. | Very Good | Very Good | A very durable enamel. |
| | | | | | | | | 94% | |
| | | | | | | | | | Na Sb O ₃ |
| | | | | | | | | | CALCITE |
| | | | | | | | | | BORIC ACID |
| | | | | | | | | | RUTILE |
| | | | | | | | | | FLUOR-SPAR |
| | | | | | | | | | SODA ASH |
| | | | | | | | | | SALT PETER |
| | | | | | | | | | CRYOLITE |
| | | | | | | | | | BORAX |
| | | | | | | | | | QUARTZ |
| | | | | | | | | | FELDSPAR |

FIG. 2.

in "A Comparison of Ten White Enamels for Sheet Steel," Vol. XIV of the *Transactions*, were followed out. The corrosion test was the same in every case, 20 per cent by volume acetic acid being used. In calculating the molecular formulas the rutile was considered as being pure TiO_2 .

These compositions were all very difficult to work as enamels and probably have no practical value as such. The principal difficulty was in keeping them suspended properly, due to the high specific gravity of the frits. They do, however, serve to show to what extremes titanium compositions might be carried and give some idea of the resulting properties.

The enamels of series B, figure 2, were made for the purpose of finding out something of the working and the properties of rutile enamels of more nearly a normal composition.

Conclusions

Some of the conclusions drawn from the above and other trials of this enamel material, which can not be given, are as follows:

I. A too high content of TiO_2 increases the specific gravity of a frit to such an extent that it is extremely difficult to keep it in a satisfactory state of suspension by ordinary means.

II. The extent of the yellow discoloration is not directly proportional to the amount of rutile and nitrate in the enamel, but seems to depend also upon other chemical balances not yet determined. Thus an enamel with a large amount of rutile and the proper per cent of nitrate may have less discoloration than one with correspondingly less of each material.

III. The opacity is also somewhat independent of the amount of rutile present. As claimed by Vondracek, TiO_2 does precipitate out of the molten solution in the form of invisible crystals, but the extent of this crystallization is, we believe, more dependent on the composition of the enamel than on the exact amount of TiO_2 present. Just what the most suitable compositions are has not yet been determined; but apparently the presence of B_2O_3 is desirable, although this constituent may be replaced entirely by TiO_2 as far as most of the resulting enamel properties are concerned.

IV. The theory of the opacity from TiO_2 by means of its precipitation within the enamel is backed by the fact that some rutile enamels are easy to overburn, especially when they are opaque and in the absence of tin oxide.

When a certain excess of crystals have formed within the enamel, they appear to break through the surface with a consequent loss of gloss. This one point might limit to some extent the procurement of the maximum opacity from TiO_2 in the melt.

V. The most promising feature of the possible use of rutile is shown by the fact that practically all enamels containing it show unusual durability under all tests. The chemical resistance is always greatly superior to the ordinary kitchen ware enamel, and the very high gloss which many of the enamels develop makes a surface which is especially resistant to abrasion and the consequent failure of the enamel after the surface is once broken. The heat resistance is also greatly improved and the resistance to impact is fully as good as is found with other average enamels.

VI. Preliminary experiments indicate that TiO_2 has no place in a ground coat. When 0.1 molecule of TiO_2 was added to a normal ground coat, the cobalt blue was somewhat destroyed, the melting point was so lowered as to cause burning off, and the enamel did not combine properly with the steel. The elasticity remained as good, however, and possibly was somewhat improved.

VII. The direct addition of 1 per cent of cobalt oxide to enamel 1 of series A did not result in any of the usual ground coat properties. The enamel was softer, more brittle, did not burn down properly and had very little adherence.

By way of final conclusions, we might say that the good qualities resulting from the use of titanium seem to more than offset the bad ones and it seems possible to overcome some of the difficulties and develop enamels of very substantial practical value.

CLEVELAND, OHIO
February, 1919

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

NOTE ON COBALT OXIDE

BY N. B. DAVIS

The history of the use of cobalt compounds as coloring agents in the ceramic industry takes one back to the early days of the Chinese civilization. The early potters were satisfied with cobalt in the form of the original ore, roasted, or in crudely made silicate melts, while the modern ceramist must have his cobalt in the highly concentrated form of oxide.

For many years the world's supply of cobalt was drawn from the cobalt-silver deposits of Saxony, and about the year 1790 the annual production of smalt blue, containing approximately 6 per cent of cobalt, was 300 tons. With the discovery and development of the nickel deposits of New Caledonia metallurgical processes were perfected for the separation of cobalt, and for some time prior to 1903 most of the world's supply came from these ores.

Between 1903 and 1908 some cobalt oxide was produced from the lead-nickel-copper-cobalt ores of Missouri, but since 1905 the greatest source of oxide has been the cobalt-silver district of Canada. The Canadian production now shows signs of decline, and it is interesting to note that the deposits of Missouri are coming to the fore again. Under new management, and with the experience gained in the metallurgy of Canadian ores, metallurgical processes have been worked out to save lead, nickel, copper and cobalt, and the American ceramic industry is no longer wholly dependent on foreign supplies.

The following table shows the cobalt oxide produced and imported into the United States:

| PRODUCTION AND IMPORTS OF COBALT OXIDE | | | | | |
|--|----------------------|-------------------|-------------|----------------------|-------------------|
| Year (a) | Production pounds | Imports pounds | Year (a) | Production pounds | Imports pounds |
| 1869..... | 811 | ..... | 1894..... | 6,763 | 24,020 |
| 1870..... | 3,854 | ..... | 1895..... | 6,400 | 36,155 |
| 1871..... | 5,086 | ..... | 1896..... | 12,825 | 27,189 |
| 1872..... | 5,749 | ..... | 1897..... | 19,300 | 24,771 |

| | | | | | |
|-----------|--------|--------|-----------|---------|---------|
| 1873..... | 5,128 | 1,480 | 1898..... | 9,640 | 33,731 |
| 1874..... | 4,145 | 1,404 | 1899..... | 10,200 | 46,791 |
| 1875..... | 3,441 | 678 | 1900..... | 12,270 | 54,073 |
| 1876..... | 5,162 | 4,440 | 1901..... | 13,360 | 71,969 |
| 1877..... | 7,328 | 19,752 | 1902..... | 20,870 | 79,984 |
| 1878..... | 4,508 | 2,860 | 1903..... | 120,000 | 73,350 |
| 1879..... | 4,376 | 7,531 | 1904..... | 22,000 | 42,353 |
| 1880..... | 7,251 | 9,819 | 1905..... | (b) | 70,048 |
| 1881..... | 8,280 | 21,844 | 1906..... | 12,887 | 41,084 |
| 1882..... | 11,656 | 17,758 | 1907..... | 487,358 | 42,794 |
| 1883..... | 1,096 | 13,067 | 1908..... | 663,101 | 1,550 |
| 1884..... | 2,000 | 25,963 | 1909..... | 986,767 | 9,818 |
| 1885..... | 8,423 | 16,162 | 1910..... | 494,975 | 6,124 |
| 1886..... | 8,689 | 19,366 | 1911..... | 340,977 | 22,934 |
| 1887..... | 5,769 | 26,882 | 1912..... | 318,804 | 31,848 |
| 1888..... | 7,491 | 27,446 | 1913..... | 22,151 | 28,729 |
| 1889..... | 12,955 | 41,455 | 1914..... | ..... | 109,484 |
| 1890..... | 6,788 | 33,338 | 1915..... | ..... | 190,145 |
| 1891..... | 7,200 | 25,483 | 1916..... | ..... | 238,934 |
| 1892..... | 7,869 | 32,833 | 1917..... | ..... | 236,822 |
| 1893..... | 8,422 | 28,164 | 1918..... | ..... | ..... |

Note (a). Production is stated for calendar years, imports for fiscal years ending June 30 until 1887, and for calendar years subsequently.

Note (b). Since 1905 the total production of mixed cobalt and nickel oxides of the cobalt smelters of the Canadian Copper Company was shipped to the U. S. to be refined, and is given in the above table under the head of production. The actual production of refined oxide was probably not more than 50 per cent of these figures.

The annual consumption of cobalt oxide in the United States amounted to approximately 240,000 pounds, and although the sum of the figures in the table does not equal this amount, except in a few years, this is merely because the cobalt materials imported were classified as some product other than cobalt oxide, *e. g.*, cobalt ore, and zaffer. Zaffer is a term applied to finely ground roasted cobalt ores or products.

Metallurgy of Cobalt

Cobalt ores may be separated into two classes, *viz.*, straight sulphides or arsenical ores. Both ores are treated by blast furnace smelting to produce a speiss from arsenical ore, and a matte from a sulphide ore. In this operation most of the iron,

sulphur and arsenic are removed although a certain amount of iron is always allowed to enter the speiss or matte.

The speiss or matte then undergoes further treatment for the recovery of silver, cobalt, nickel, and copper. Sulphuric acid is used to leach the cobalt and nickel, but at the same time small quantities of iron, arsenic, and sulphur dissolve and must be removed.

When copper is present in important amounts, it is removed as metal by electrolytic means. When present in a very small amount it is eliminated along with iron by the addition of calcium carbonate. The subsequent separation of cobalt and nickel is attained by the addition of bleaching powder resulting in the precipitation of cobalt hydroxide, and the nickel is in turn precipitated by the addition of lime or sodium carbonate. The resultant black cobalt oxide will contain up to 0.5 per cent iron; 1 per cent nickel; with copper, arsenic, and sulphur 0.1 per cent each.

The cobalt hydrate is heated at low temperature to form the cobalto-cobaltic oxide (mixture of Co_3O_4 and Co_6O_7) which is black in color. This is the material supplied to the ceramic trade of U. S. and Europe. By subjecting the black oxide to temperatures around 1000°C . oxygen is driven off, and the resultant material is largely cobalt monoxide, gray in color. This gray oxide is the form in which cobalt is supplied to the trade of Japan and China.

The various salts are prepared by treating the oxide with suitable acids, the analyses of which show the following content of cobalt metal:

| | |
|-----------------------|-----|
| Black Oxide..... | 70% |
| Gray Oxide..... | 75 |
| Cobalt Arsenate..... | 29 |
| Cobalt Carbonate..... | 50 |
| Cobalt Phosphate..... | 34 |

Uses of Cobalt

Up until a few years ago the ceramic industry was the chief consumer of cobalt oxide, but recent developments in the use of cobalt metal in the manufacture of cutting tools and in the preparation of driers for soya bean oil suggest the possibility of the ceramist having to share the limited resources of the element.

In the ceramic industry the chief value of cobalt is as a coloring agent in the decoration of glass and pottery. Large quantities are consumed by the enameling sections of the trade, and a small amount added to the general body mixtures for white ware to counteract the yellow color of iron.

The tool metal trade is taking an increasing amount of cobalt metal for use in the making of Stellite, an alloy of cobalt, tungsten, and chromium. And again, the paint and varnish industry has recently found a wider use for soya bean oil through the application of cobalt linoleate as a drier. This comparatively recent development bids fair to replace linseed oil by soya oil in large measure.

Future Conditions

The price of cobalt oxide prior to 1907 varied from \$1.60 to \$2.00 per pound (70 per cent metal), but in 1907 the price rose to \$2.50 per pound. In the following years there was an overproduction from Canada and New Caledonia, resulting in a decline to an average of 90 cents in 1915. As the demand increased the price advanced to the present day quotation of \$1.50 per pound.

Looking into the future and taking into consideration the rapid growth of ceramics, tool metal manufacture, and the requirements of the paint and varnish trade, there is every indication that the price of cobalt oxide will advance. As the world resources are known to be limited in extent, and the output from most of the largest productive centers is falling off, it will probably require higher prices to develop fresh deposits.

NOTE.—For details of the subject of cobalt, its occurrence, properties and uses, the reader is referred to the recent monograph by Dr. C. W. Drury, published by the Ontario Bureau of Mines, 27, Part III, 1918.

CERAMIC ABSTRACTS

General

Melting point methods at high temperatures. I. LEO I. DANA AND PAUL D. FOOTE. *Chem. and Met. Eng.*, **22**, 23-29 (1920).—Use of Thermo-Electric Pyrometers, Pure Materials. Of all crucible materials used for pure metals Acheson graphite has the greatest utility. It is very pure, can be machined into any desired shape, and is not attacked by most of the common metals. Crucibles of magnesia, alumina or mixtures of the two are suitable for iron and nickel. Porcelain crucibles may be used for many of the metals, but there is always danger of these cracking when the metal melts or freezes. Up to 500° C. protection tubes and insulating tubes for the couple made of pyrex glass are useful. From 500 to 1100° C., lower grade porcelain glazed on the outside only or fused quartz are satisfactory. Above 1100° C. tubes having a composition approximating that of sillimanite, Al_2O_3 , SiO_2 , are recommended. The more common metals which can be used for the standardization of thermocouples by the crucible method, with their melting point in °C are: Tin 231.9, bismuth 271, cadmium 320.9, lead 327.4, zinc 419.4, antimony 630.0, aluminum 658.7, silver 960.5, gold 1062.0, copper 1083.0, nickel 1452. Furnaces wound with "Chromel A" wire are used up to 1000° C. In alloys and mixtures if the ordinary temperature-time curve does not give evidence of a melting range or of a transformation point, the more sensitive inverse rate method and differential method may be employed. The former consists in determining the time required for the specimen to fall a definite temperature interval, and in plotting this time against the temperature. The differential method is still more sensitive and consists in measuring the temperature differences between the material in which the transformation takes place and a neutral body having no transformation points in the same temperature interval, such as platinum or nickel, and plotting this difference against the temperature of the material.

H. P. NIXON.

Melting point methods at high temperatures. II. LEO I. DANA AND PAUL D. FOOTE. *Chem. and Met. Eng.*, **22**, 63 (1920).—The use of optical pyrometers is necessary above 1550° C. The disappearing filament type is most satisfactory. Melting points of refractory oxides in °C. are: MgO 2800, CaO 2570, Al_2O_3 2050, Cr_2O_3 1990. For technical testing the criterion of marked flow is usually taken to define the so-called melting point for refractory mixtures and even for pure crystalline compounds; on the basis of such a definition the melting point of quartz is about 1750° C. Crushed carbon, graphite, kryptol, or carbon plate resistor furnaces do not permit of very precise regulation. The vacuum furnace of the Arsem type

is more desirable on account of its freedom from smoke and because good control is possible at extreme temperatures, even at 2500°C . Seger and similar cones serve a useful purpose under slow rates of heating in measuring heat effects during the firing of ceramic products, but in the laboratory, when the rates of heating are comparatively rapid and may vary considerably, the determination of the cone softening point is not of much significance.

MELTING POINTS OF COMMON REFRACTORY MATERIALS

| Fire bricks | $^{\circ}\text{C}$. | Clays and sands | $^{\circ}\text{C}$. |
|-----------------|----------------------|---|----------------------|
| Fire clay | 1500-1750 | Kaolin, $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ | 1740 |
| Silica | 1700-1750 | Fire clays | 1400-1740 |
| Magnesia | 2150 | Bauxite clay | 1800 |
| Bauxite | 1600-1800 | Bauxite, $\text{Al}_2\text{O}_3(\text{OH})_3$ | 1820 |
| Chromite | 2050 | Chromite, $\text{FeO} \cdot \text{Cr}_2\text{O}_3$ | 2180 |
| Miscellaneous | | | |
| Coal ash | 1100-1500 | Silica | 1750 |
| Alundum cements | 1750-2000 | Silica sands | 1700-1750 |

H. P. NIXON.

Research associations, growth of, in England. Staff article. *Chem. Met. Eng.*, 22, 264 (1920).—Under the British Government's plan, whereby \$4,866,500 is made available for industrial research, research associations have been formed in connection with a large number of industries including the portland cement and glass industries. The scientific and industrial research department has given its sanction to the formation of similar associations for refractory materials. Before any association can come under the government scheme, the associations must be national in character and include the bulk of the manufacturers in any specified industry. The general scheme is to provide £1 from the department for every £1 subscribed by members up to five years after organization; but should an association's expenditure exceed £6,000 a special arrangement may be agreed to.

A. J. LAMBERT.

Insulating materials, electrical resistance of various, at high temperatures. R. K. HONEMAN AND E. L. FONESCA. *Report No. 53*, National Advisory Committee for Aeronautics, p. 15.—In very hot high-compression engines spark plugs may fail because the core becomes a conductor of electricity. The ignition current then flows through the body of the plug instead of causing a spark at the terminals. To secure definite and repeatable results on this property, it was found necessary to make the measurements with alternating current, using a 500-volt, 60-cycle supply. In this way the disturbing effect of polarization, etc., is avoided. The conductivity of this class of materials increases very rapidly with temperature according to the law of compound interest at a rate of about 2 per cent per degree centigrade. The most convenient basis of comparison for different materials is the "effective temperature" (T_e) to which they must be heated in order to reduce their resistivity to a definite value, arbitrarily taken as one megohm per cm. cube. A spark

plug of normal design with material of this resistivity would have a resistance of about 200,000 ohms. This value is only slightly above the limit at which the usual ignition system can be counted on to fire a plug. The effective temperature thus defined varies from 870° C. in case of fused quartz (the best material tested) down to 280° C. for some kinds of glass. Porcelains have been developed at the Bureau of Standards ceramic laboratory which have an effective temperature as high as 800° C. Certain bodies recently developed for use in aviation engines have temperatures of about 650° C., while the majority of spark-plug porcelains have 500° C. A material having T_e less than 400° C. should be used only when the design of the plug is such that the insulator is extremely well cooled. The T_e temperature in C° for typical materials is as follows: Fused silica 890; best porcelain tested 790; typical mica plug 720; average of three aviation porcelains 650; average automobile porcelain 490.

H. G. SCHURECHT.

American bond clays, the properties of and their use in graphite crucibles and glass pots. A. V. BLEININGER. Bureau of Standards, *Tech. Paper*, 144. —The properties of American bond clays are described in detail and expressed through characteristic numerical values with special reference to their burning behavior. For crucible making the best clays should show a pore-shrinkage water ratio of not more than 1 : 1; a modulus of rupture for a clay-sand mixture of 1 : 1 of about 325 pounds per square inch; a vitrification point of 1150° C., or lower; no marked evidence of overfiring at 1400° C. and a softening point corresponding to Orton cone 31, or above. For glass pots the best materials should show a pore-shrinkage water ratio of not more than 1 : 1; a modulus of rupture, when mixed with equal weights of sand, of not less than 250 pounds per square inch; a vitrification temperature of approximately 1275° C.; an overfiring temperature not below 1425° C.; and a softening point equivalent to Orton cone 29, or above. It is shown that materials equal in quality to those formerly imported from Germany are available and that by suitable blending any desired combination of properties can be readily produced. The characteristics of natural and artificial graphite are described and means suggested for the control of crucible mixtures. The fact is brought out that the main advantage in the use of German glass pot clay consists in its low fire shrinkage and suggestions are made for obtaining similar conditions with the use of domestic materials and with increased resistance to corrosion. The compositions and the preparation of semi-porcelain and porcelain glass pots are given. The method of casting glass pots as practiced at the Pittsburgh laboratory of the Bureau of Standards is also described.

A. J. LAMBERT.

Kaolin, ceramic and paper. H. LERG. *Tonind. Zeit.*, 44, 103 (1920).—Washed kaolin is passed through long troughs and the portion which sinks to the bottom is used for paper, while the finer kaolin which is carried off by the water is used for ceramic purposes. About two parts of paper kaolin are obtained from three parts of the total.

H. G. SCHURECHT.

Osmotic purification of clay. W. R. ORMANDY. *Trans. Ceram. Soc.*, 18, Pt. II, 327-339 (1919).—The apparatus consists of a wooden trough, fitted with a lining of wire gauze, and a metallic drum which rotates slowly in the trough. At any point clay and water to which has been added a small amount of alkali, can be fed in. An overflow is provided through which the impoverished slip can be discharged. The gauze is connected to one electric pole, and the drum to another, and an electric current is set in motion. A thin deposit of clay forms on the drum, and gets thicker and thicker, and although deposited actually *under the water* the clay is found to come off drier than by the use of an ordinary filter press at a pressure of 150 pounds to the square inch. The cause of the dryness is that the clay particles which are near the electric pole come on to its surface owing to their electric charge and form a very thin layer or skin. This skin, owing to the fact that it is made up of a number of very small particles, consists of a series of capillary tubes, and instantly the water is sent away in accord with the well-known phenomenon (known as endosmosis) of travel of water through capillary tubes under the influence of electric current. Most bodies when placed in water take on a negative charge of electricity. Generally speaking, pyrites and iron oxide are positive, while silica is practically neutral, and clay electro-negative. The addition of a small amount of alkali causes certain particles to accumulate into a smaller number of a larger size due to neutralization of their electric charge, and these settle out rapidly. Purification of clays by deflocculation by the addition of alkalies and sedimentation is used preliminary to osmotic purification. The product which is separated by the treatment is recovered in a comparatively dry state, it has always an increased plasticity, it sinters at a temperature which may be anything up to 300° C., lower than that of the original clay, it shows a greater contraction and has always a higher melting point.

A. J. LAMBERT.

Recuperative furnace, a new type of. WALTER ROSENHAIN AND E. A. COAD-PRYOR. *Trans. Ceram. Soc.*, 18, Pt. II, 407-419 (1919).—See this JOURNAL, 2, 838.

A. J. LAMBERT

Research, industrial at the Mellon Institute. WALLACE SAVAGE. *Chem. & Met. Eng.*, 22, 249-255 (1920).—Two and one-half years ago the Refractories Manufacturers' Association founded a multiple fellowship at the institute for the main purpose of developing standard tests for refractories. Much valuable information has been obtained on fusion, slag penetration and abrasion, spalling, deformation under load on reheating and volume changes on reheating. In the case of magnesia, extensive investigations are being conducted to develop a domestic product to replace that formerly imported. The effect of the basic fluxes, such as lime, iron oxide, etc., on the slaking, slagging and general stability in use was sufficiently determined to give the data required for the production of satisfactory magnesia products from domestic magnesite. The elimination of the lami-

nated structure in auger machine made brick by repressing the brick on edge is another industrial contribution of this fellowship.

Dr. C. C. Vogt, working on the dental cements fellowship, by the proper blending of metal oxides and such fluxes as feldspar, silica and fluorides, has perfected a new translucent dental cement which has been nationally adopted by the dental profession.

J. L. CRAWFORD.

Soap from clay. *Brick Clay Record*, 55, 533 (1920).—It is reported in England that F. E. Weston has made a long series of experiments in the use of colloidal clay in the soap manufacture. The washing properties of soap derived at present from fatty acids from animals and plants can equally well or even better be partly supplied by colloidal clay. China clay is treated by a special colloidal process through which colloidal clay is prepared. Since the price of soap is largely dependent upon the proportion of fatty acids it would seem that the substitution of colloidal clay for these would cheapen the cost of soap. It is not contended that these fatty acids can be dispensed with entirely by the use of colloidal clay; but their present proportion could be reduced one-half by the substitution of colloidal clay.

H. G. SCHURECHT.

Refractories

Bricks, preventable defects in refractory. C. E. NESBITT AND M. L. BELL. 19, Part II, 620-629.—The strength of a brick is greatly reduced by penetration of slag. A dense brick is advocated. Tests made for slag resistance on experimental power-pressed silica brick show approximately 25 per cent less penetration by heating furnace slag than hand-molded brick. Silica brick shows a marked falling off of from 50 to 60 per cent in crushing strength when heated to 1350° C. A group of 85 standard 9-in. silica bricks were subjected to visual inspection; 16 were judged to be of low strength because of visual defects; 18 were considered to be of medium strength, while the remainder were passed as being good. These bricks were then subjected to a hot crushing test. All bricks were crushed at 1350° C., with the result that the average strength for the 16 defective bricks was 677 lbs. per sq. in., 861 lbs. for the medium and 991 lbs. for the good bricks. True specific gravity and porosity tests tell only the degree of burning—D. W. Ross, "Silica Refractories," *J. Am. Ceram. Soc.*, 1, 477 (1918). Bricks which have the same true specific gravity do not have the same crushing strength or spalling value. Uniformity of product is important. A. J. LAMBERT.

Fire clay, the use of, in laying fire clay brick. R. M. HOWE. *Clayworker*, 136-137 (1920).—Certain materials such as cement and sodium silicate are sometimes added to fire clay mortars in laying fire clay brick in order to reduce the shrinkage and to prepare a mortar which will harden without burning. The effects of these ingredients on the fusibility of a cone 30 bond clay were studied and the results are given below.

DEFORMATION POINT OF THE MIXTURES EXPRESSED IN CONES

| Per cent material added | Portland cement | Lime | Asbestos | Water glass | Salt | Carborundum | First grade fire-brick bats |
|-------------------------|-----------------|-------|----------|-------------|------|-------------|-----------------------------|
| 0... | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| 3... | .. | .. | 28-29 | .. | .. | .. | .. |
| 4... | 27 | 20-26 | .. | 29-30 | .. | .. | .. |
| 5... | .. | .. | .. | .. | 26 | 29 | .. |
| 6... | 20 | .. | 19-20 | .. | .. | .. | .. |
| 8... | 19 | 17-18 | .. | 29 | .. | .. | .. |
| 9... | .. | .. | 18-19 | .. | .. | .. | .. |
| 10... | 15 | .. | .. | .. | 14 | 29 | .. |
| 12... | .. | 11 | .. | 28-29 | .. | .. | .. |
| 15... | .. | .. | .. | .. | 5 | 29 | .. |
| 16... | .. | 10 | .. | 26-27 | .. | .. | .. |
| 20... | 13 | .. | .. | 26 | .. | 29 | .. |
| 24... | .. | .. | .. | 20 | .. | .. | .. |
| 25... | .. | .. | .. | .. | .. | .. | 30-31 |
| 30... | 11 | .. | .. | .. | .. | 29 | .. |
| 40... | 8 | .. | .. | .. | .. | 29 | .. |
| 50... | .. | .. | .. | .. | .. | 29 | 31 |

The addition of first quality brick bats to the bond clay produced the most refractory mixture. The writer emphasizes the harmful results obtained by the addition of certain foreign materials like Portland cement and asbestos, which greatly decrease the refractoriness of the mortar. Arches with a thick mortar containing 10% each of asbestos and water glass failed at 1250° C., due to softening of the mortar. The use of an extremely thin layer of mortar is recommended.

H. G. SCHURECHT.

Crucible graphite. Staff article. *Chem. and Met. Eng.*, 22, 220 (1920).—Graphite for making crucibles should be of the crystalline variety and should have a high degree of purity. Most makers of crucibles prefer to use Ceylon graphite either alone or mixed with varying proportions of American flake, usually not exceeding 25% of the mixture. The more nearly cubical fragments of Ceylon graphite have a much smaller surface area in proportion to their volume than the thin flakes of domestic graphite and hence require proportionately less clay as a binder. It is possible, however, to use domestic flake graphite alone with success. The graphitic carbon contents of No. 1 flake should be not less than 85%. Graphitic carbon is the carbon remaining after the dried sample has been burned for 3 min. at 800° C. Screen analysis for No. 1 flake recommended are: Over 35 (standard) mesh—3%, over 65 (standard) mesh—50%, over 100 (standard) mesh—100%.

Although flake carrying 85% of graphitic carbon can be readily produced, the cost of a product containing 90% of graphitic carbon is very greatly increased. A sample of Ceylon graphite prepared for crucible use contained

85.06% of graphitic carbon. In purity, therefore, the American graphite compares favorably with that from Ceylon. The past ten years has seen rapid increase in the manufacture of electric furnace steel, while the production of crucible steel has remained stationary. Recent developments in the electric furnace as applied to non-ferrous alloys also give promise of a rapid decrease in the use of crucibles.

H. P. NIXON.

Refractories for glassworks' use, specifications for. W. T. REES. *Trans. Ceram. Soc.*, 18, Pt. II, 420-430 (1919).—These provisional specifications have been adopted by the Council of the Society of Glass Technology and accepted by the Committee nominated by the Employers' National Council for the Clay Industries. *Tank Blocks:* At the request of the purchaser the following data shall be supplied for his personal information only, together with average samples true to bulk. (a) Analysis, showing content of silica, alumina, iron oxide, titanium oxide, lime, magnesia, potassium oxide, and sodium oxide. (b) Refractoriness measured by Seger cones. (c) Volume porosity. (d) Linear contraction or expansion after being heated to a temperature equivalent to cone 14. (e) Crushing strength. *Tests.*—1. *Refractoriness:* Cones cut from the blocks shall not be more fusible than cone 30. The test shall be carried out in an oxidizing atmosphere, the temperature of the furnace being increased regularly at the rate of 50° C. per five minutes. 2. *Texture:* The block shall contain no patches of iron-stone or other segregated impurity. They shall be uniformly burnt throughout, and if any blue, black or brown core is present, it shall be of the minimum extent practicable, having regard to the size of the block. The blocks shall be of regular texture and free from holes and flaws. The arrasses shall be as reasonably sharp as is consistent with the size of the grog used. All surfaces shall be sufficiently true and plain as to permit of the blocks being walled together without appreciable joint space on the exposed face. 3. *Porosity:* The volume porosity, *i. e.* (the volume of pores \times 100) \div volume of piece (including pores), shall not exceed: For flux line blocks 18 per cent, for replacement flux line blocks 25 per cent, for bottom side blocks 25 per cent, for tank bottom blocks 30 per cent. 4. *After-contraction or After-expansion:* Test pieces (about 3 inches in length and 1 and 2 inches in depth and breadth) taken from any portion of the block after being heated to, and maintained for two hours at a temperature equivalent to cone 14, shall not show when cold more than 2 per cent linear contraction or expansion. When the test temperature has been reached the furnace shall be maintained constant throughout the test period. 5. *Crushing Strength:* The blocks shall be capable of withstanding a crushing strain of not less than 1,600 pounds per square inch. The portion of block tested shall be a 4-inch cube and shall have the two ends which come in contact with the jaws of the machine ground or sawn flat and made truly parallel by facing with plaster of Paris in the usual way. 6. *Inspecting and Testing:* The purchaser or his representative shall have access to the works of the maker at any reasonable time, and shall be allowed to inspect the blocks before delivery. Duplicate test pieces representative of the bulk of the

material ordered shall be selected prior to delivery. The cost of the blocks damaged for the purpose of obtaining test pieces shall be borne (a) by the purchaser when the material is proved satisfactory; (b) by the maker, if unsatisfactory. *Raw Clays and Grog.*—1. *Mixture:* Clay mixture for pots shall consist of at least three portions: (a) Bind clay, (b) base clay, (c) grog. At the desire of the buyer the following data shall be supplied with samples true to bulk. 2. *Analysis:* The analysis shall show content of SiO_2 , Al_2O_3 , K_2O , Na_2O , TiO_2 , CaO , MgO , Fe_2O_3 , and the loss on ignition. 3. *Fusion Test:* This shall record: (a) Squatting temperature, measured by Seger cones, with equivalents in $^{\circ}\text{C}$. and $^{\circ}\text{F}$. (a) Squatting temperature under load in $^{\circ}\text{C}$. and $^{\circ}\text{F}$. by standard test to be defined. 4. (a) The bind clay shall be a fat plastic, aluminous weathered clay. (b) The base clay shall be a highly refractory clay. Lumps to be specially selected and hand-picked free from pyrites. (c) The grog shall be prepared from well-burned pieces of selected refractory clay. Burnt blocks must show no sign of blue-stoning or black core. Nothing of the nature of ordinary fire brick shall be used for grog. 5. A sample of any portion when made up and fired to $1,400^{\circ}\text{C}$. shall not show decided speckling due to iron in a segregated form. 6. A fracture of each portion, when made up and burnt to $1,400^{\circ}\text{C}$., shall show a dense structure, especially the bind clay. A wide range of vitrification is necessary without signs of over-firing. 7. Clay and grog shall be loaded in clean bags securely tied. *Silica Bricks and Cement.*—At the desire of the purchaser the following data shall be supplied for his personal information only, with average samples true to bulk: (a) Analysis, (b) refractoriness, (c) linear expansion after being heated to cone 12. 1. *Composition:* The bricks shall contain not less than 94 per cent of silica, and not more than 2 per cent of lime. 2. *Refractoriness:* Test pieces shall not be more fusible than cone 32 (about $1,710^{\circ}\text{C}$.). The test shall be carried out in an oxidizing atmosphere, the temperature of the furnace being increased at the rate of about 50°C . per five minutes. 3. *After-expansion:* A test piece after being heated to a temperature equivalent to cone 12 for two hours shall not show, on cooling, more than 0.75 per cent linear expansion. 4. *Texture:* The bricks shall be uniformly burnt and shall have a regular texture with no holes or flaws. 5. *Variations from measurements:* All surfaces shall be reasonably true, and there shall not be greater variation than 2 per cent from any specified dimension. Silica cement shall in all cases be finely ground and suitable for binding together the bricks for which it is supplied. It shall contain not less than 92 per cent of silica and shall be capable of withstanding the same test for refractoriness as the brick. In the discussion emphasis was laid on the fact that these specifications are too stringent in some respects.

A. J. LAMBERT.

Refractory materials, the geology of the, of the North of England. J. B. ATKINSON AND J. T. STOBBS. *Trans. Ceram. Soc.*, 18, Pt. II, 435-455 (1919).—The fire clays have no doubt accumulated under water from debris washed down by rivers. They are generally but not always associated with coal

beds. A quarry at Pensher in Durham now furnishes blocks of the sand stone called "fire-stone," for the construction of tanks for holding molten glass. It is probable that the highly siliceous ganister rock in this district has long been used in its natural state as a refractory. Ganister rock, generally mixed with fire clay and other materials, for the purpose of making "ganister bricks," would appear to have been first used near Sheffield, about 1858 or 1859.

A. J. LAMBERT.

Refractory materials, the standardization of tests for. COMMITTEE REPORT. *Trans. Ceram. Soc.*, 18, Pt. II, 516-17 (1919).—The penetrative action of slags on fire clays and fire bricks can be conveniently examined in three ways. In the first the clay mixture can be pressed into hollow blocks; outside $2\frac{1}{4}$ inches square, $1\frac{1}{2}$ inches deep; inside $1\frac{3}{4}$ inches deep. The blocks are fired to the desired temperature, say cone 10. When cold, the desired slag is placed in the receptacle and the whole is then again fired to the desired temperature for the desired period of time, say 4 hours. When cold the block can be sawn across. The penetrative and corrosive action of the slag on the mixture will then appear. In the second method a hole, say 2 inches diameter and $\frac{1}{2}$ inch deep, is bored in the brick and filled with slag. The whole is then fired and treated as in the previous case. In the third, a ring of stoneware is cemented to a fire brick by means of a thin film of fine grog and silicate of soda mixture. The receptacle so formed is filled with slag and the whole is treated as before. The penetrative action of the slag can then be examined by sawing the brick across. This plan is of general application to fire bricks and gives good results.

A. J. LAMBERT.

Mortar refractory. R. KLINGER. *Tonind. Zeit.* 44, 17 (1920).—A good refractory mortar should increase in strength during service as lime-mortars do when used with building brick. It should not melt at the temperature of the furnace and should show a small fire shrinkage. The chemical analysis should be adapted to the type of brick it is used with.

H. G. SCHURECHT.

Mortar refractory. W. B. SCHEIDT. *Tonind. Zeit.* 44, 86-87 (1920).—S. discusses paper on "Refractory Mortar" (*Ibid.*, 44, 17 (1920)). Fusion to a certain degree is desirable in refractory mortar as this binds brick together, whereas if the mortar was not fused the brick work would be more or less loose. In furnaces where the mortar is too refractory large cracks occur, due to the expansion and contraction of the brick work due to heating and cooling.

H. G. SCHURECHT.

Mortar refractory. R. KLINGER. *Tonind. Zeit.* 44, 132 (1920).—Cracking of the brick work in furnaces seldom occurs in a new furnace where the mortar is still in an unfused state, while later on when this mortar becomes fused there is a decided tendency for the brick work to crack.

H. G. SCHURECHT.

Silica bricks, factors influencing the properties of. I. ALEXANDER SCOTT. *Trans. Ceram. Soc.*, 18, Pt. II, 481-596 (1919).—The method of investigation consisted in bonding as pure a silica rock as possible with a small percentage of other material, firing to various temperatures and examining the bricks so made. The silica rock used was vein quartz of a fairly high degree of purity. The bonding materials used were as follows: A, lime (CaO). B, magnesia (MgO). C, alumina (Al₂O₃). D, iron oxide (Fe₂O₃). E, iron oxide (Fe₂O₃) + carbon. F, titanic oxide (TiO₂). G, lime and magnesia. H, lime and alumina. I, lime and iron oxide (Fe₂O₃). J, lime, iron oxide and carbon. K, lime and titanic oxide. L, magnesia and alumina. M, magnesia and iron oxide. N, magnesia, iron oxide and carbon. O, alumina and iron oxide. P, alumina, iron oxide and carbon. Q, lime, iron oxide and titanic oxide. R, Glenboig fire clay. S, china clay. The amount used was 2.5 per cent in the case of the simple oxides, 1.25 per cent of each where two oxides were used, and in Q 1 per cent of each. The carbon was ordinary charcoal and the amounts of E were 2.5 per cent oxide and 0.5 per cent charcoal and in J, N, P, 1.25 per cent of each oxide and 0.25 per cent charcoal. The percentage of unconverted quartz in bricks fired to cone 19 was measured microscopically.

| Binder | A | B | C | D | E | F | G | H | I |
|------------------|------|------|------|------|------|------|------|------|------|
| Quartz %..... | 61.4 | 65.4 | 76.5 | 57.1 | 58.8 | 68.5 | 71.2 | 60.0 | 51.3 |
| True sp. gr..... | 2.51 | 2.56 | 2.61 | 2.51 | 2.49 | 2.57 | 2.57 | 2.52 | 2.45 |

| Binder | J | K | L | M | N | O | P | Q | R | S |
|------------------|------|------|------|------|------|------|------|------|------|------|
| Quartz %..... | 52.1 | 62.7 | 65.7 | 63.3 | 62.0 | 52.5 | 61.7 | 49.0 | 58.3 | 62.0 |
| True sp. gr..... | 2.46 | .. | 2.55 | 2.54 | 2.55 | 2.46 | 2.47 | 2.44 | 2.49 | 2.53 |

The true specific gravity may be taken as giving a qualitative idea of the amount of conversion, but the quantitative relation is only approximate. As the values for true specific gravity of bricks heated to cone 26 are all practically the same, and approximate to the specific gravity of cristobalite, it may be assumed that most of the quartz has been converted. Hence, it seems feasible to take the after-expansion at cone 26 as indicative of the total expansion of the material during conversion. The ratio of the after-expansion at cone 26 and cone 16 varies from 6.7 to 23.8. Hence, the after-expansion test carried out at cone 16 or lower temperatures may not give even an approximate idea of the expansion which will occur during use. In order to get such an idea it is necessary to heat either to a much higher temperature than cone 16, or for a more prolonged period. In the case of those blocks which contain lime or magnesia as one constituent, final softening is due to the fusion of the mixture of silicates and fine-grained free silica in the matrix. Where the bond consists of alumina or iron oxide, or a mixture of the two, the matrix and rock fragments seem to fuse simultaneously and the softening point of the piece is practically the same as that of silica. The absence of squatting is due to the high viscosity of fused silica. Fire clay acts in a very similar way. All samples softened at cone 33-36.

A. J. LAMBERT.

Silica brick from roof of a basic open-hearth furnace after 135 charges. C. S. GRAHAM. *Trans. Ceram. Soc.*, 18, Pt. II, 399-406 (1919).—The change in volume of cristobalite at 230° is considerable, consequently mercury dilatometer observations offer a sure way of distinguishing cristobalite from tridymite. The wear and tear of silica bricks in basic open-hearth furnaces is to a certain extent due to the abrasive action of the fine basic dust swept through the furnace by the producer gas. Other factors are high working temperatures, local effects of flame, dust in materials charged, liquid metal from bath and charge, and spurting of the slag during boiling of the bath. The fused material is swept away and fresh surfaces exposed for attack, until the bricks are worn away, the maximum wear being near the transverse center of the furnace. The color of the zone exposed directly to the furnace temperature was gray, being followed by a black, a yellow, and a red zone. The gray and black zones were divided by a distinct line of demarcation, while the transition of black to yellow was a gradual one. From yellow to red again was a sudden change.

| Zone | Unused brick | 1 | 2 | 3 | 4 |
|----------------------------|--------------|-------|--------|-------|-------|
| Depth of zone, inches | | 1/2 | 3/4 | 3-1/4 | 1-3/4 |
| Color of zone | | red | yellow | black | gray |
| Silica..... | 95.0 | 93.7 | 91.4 | 85.5 | 88.6 |
| Alumina..... | 1.1 | 1.1 | 1.8 | 1.5 | 1.0 |
| Total iron, ferric oxide.. | 1.0 | 1.14 | 1.52 | 5.94 | 5.52 |
| Manganese oxide..... | trace | trace | trace | .27 | .37 |
| Lime..... | 2.5 | 3.19 | 4.10 | 6.06 | 4.04 |
| Bulk, specific gravity... | 1.65 | 1.78 | 1.80 | 2.14 | 2.14 |
| True, specific gravity... | 2.37 | 2.41 | 2.41 | 2.44 | 2.42 |
| Porosity, per cent..... | 30.4 | 26.1 | 25.3 | 12.3 | 11.6 |

Microscopic examination showed structures similar to those described by others.

A. J. LAMBERT.

Glass

Glassware, present status of American. E. C. SULLIVAN. *Chem. and Met. Eng.*, 22, 29 (1920).—America has long been the acknowledged leader in ornamental cut-glass, no other country having equalled the brilliance and richness of the American product. An art glass which had its origin in America is the well-known Aurene or Favreuil glass, of golden iridescence, produced by spraying upon the surface of the finished article a liquid which reacts with the constituents of the glass and produces very remarkable soft color effects. Selenium red glass originated in this country and is used universally by railways in this country for the danger signal. In other railway signal glasses also this country is well in the lead, both in design of the semaphore lens and in production of the most efficient colors. Another advance due to America was the introduction of low-expansion so-called heat-resisting glass for railway lantern globes. For electric light bulbs non-potash glass has been in use for some years and in many respects gives better results than the potash

glass which it replaced. Two or three years ago a tank-melted bulb-glass was successfully introduced which contained neither potash nor lead, and its use has extended until a very large proportion of all lamp bulbs are now made of comparatively inexpensive materials. Selective Spectrum-Absorbing Glass. A very pale but brilliant yellow glass which absorbs ultra-violet almost completely has been developed. A recent American glass transmits ultraviolet and absorbs the visible. "Welders' glasses" have been worked out which absorb not only ultraviolet but also infra-red and such excess of the visible light as causes glare. Another unique glass absorbs only the infra-red. It is of pale green color and transmits most of the visible, but in thickness of only 2 mm. absorbs 95% or more of the invisible heat-rays. A glass for X-ray shields which had about one-third the protective power of metallic lead of the same thickness was developed during the war and was the most effective glass used for the purpose up to that time. Better chemical glassware is made in this country than was ever imported. The glass baking dish is a purely American development. American clay pots are giving in every respect fully as satisfactory service as was had from the imported material.

H. P. NIXON.

Glass decolorizers and their influence. Schnurpfel's Review for Glass Works, 3, 499, 513 (1919).—The greenish tint in glass is due to iron compounds while the deepness of the tint depends upon the materials and the temperature of the furnace. The tint is neutralized by the use of nickel oxide, cobalt oxide, manganese oxide, antimony oxide, selenium and arsenic. Nickel oxide is most used. Requires 1 to 3 gr. per 100 kg. of sand and becomes effective at the end of the melt, due to its high melting point. Cobalt is often used with talcum and antimony. The yellow of the antimony offsets any excess of blue. Use $\frac{1}{4}$ to $\frac{1}{3}$ gr. of cobalt per 100 kg. of sand. Manganese gives a wine-red tint but may also give a yellow in soda glasses. Use 250 to 300 gr. for 100 kg. sand. The action is uncertain in tank furnaces. Antimony oxide is of doubtful value. When used it requires 220–250 grs. of antimony with an equal quantity of manganese for 100 kg. of sand. It is injurious to the pot as metallic precipitations settle at the bottom and corrode it. It increases the brilliancy of the glass. Satisfactory in tank furnaces. Selenium requires a high furnace temperature. Use 1–2 grs. per 100 kg. of sand. It is hard to get just the right amount. Arsenic clarifies the melt and oxidizes the carbon and sulphur compounds. Use 200 to 500 grs. or more per 100 kg. of sand. It boils at 412° C. causing active ebullition.

R. J. MONTGOMERY.

Water-glass, a colloidal method for increasing the volume of adhesive. J. D. MALCOLMSON. *J. Ind. Eng. Chem.*, 12, 174 (1920).—Commercial silicate of soda of d. 42° Be is used in very large quantities in the fiber container industry, being now the only adhesive material employed for gluing double-faced corrugated board and laminated solid fiber board. A method has been found for increasing the vol. without injuring the essential properties

which make water-glass of especial value to the box-board industry. These properties are classed as follows: (1) Adhesive value; (2) proper viscosity; (3) low penetration; (4) fast setting and drying rate (the boards are run through the pasting machines at a speed of upwards of 60 ft. per min.); (5) relative insol. when dry; (6) relative flexibility when dry; (7) negligible effect of age; (8) relatively low cost. The method consists of dil. the water-glass with brine and it was found possible to increase the vol. of the soln. by 25% without loss of any of its essential properties. Water-glass is a complex mixture of sodium silicate, water and silica in the colloidal state. The adhesive grade usually contains $3-3\frac{1}{2}$ parts of SiO_2 to 1 of Na_2O . When an electrolyte is added the colloidal silica is coagulated forming a "weakly agglutinated gel" which undisturbed coalesces to a dense mass; however, if this is stirred during the addition and for a short time afterwards the gel particles go back into "soln.," *i. e.*, "peptized." The peptization of the gel is accompanied by an enormous increase in viscosity over that which results from plain water dil. Twenty-five per cent increase in vol. was found to be the max. efficient amount; larger amounts of brine makes the peptization process increasingly difficult. The cost of treatment is low, since the treated water-glass contains only 3-4% by wt. of NaCl .

F. GELSTHARP.

Glass and glassware, Japanese. O. P. HOPKINS. *J. Ind. Eng. Chem.*, **12**, 112 (1920).—Removal of Belgium, Germany and France from trade in Far East stimulated the Japanese industry. Increased imports from Japan consisted of beads and other glass. The increased exports from U. S. to Japan have been largely plate glass, formerly supplied by Europe. They have the advantage over competitors of low wages and laborers adapt themselves readily because of previous experience in pottery and similar lines. The av. daily wage for males being 38 cents and 17 cents for females. The SiO_2 used in a factory with a yearly production of 100,000,000 sq. ft. of window glass is obtained from Korea and Anam and is of excellent quality. The machinery in this factory is practically all driven by electric power.

F. GELSTHARP.

Glasses, the ultra-violet and visible transmission of eye-protective. K. S. GIBSON AND M. J. McNICHOLAS. Bureau of Standards, *Tech. Paper* **119**.—A description is given of the method of making transmission measurements. Various instruments were used, including the Hilger sector apparatus, the Lummer-Brodhun and Koenig-Martens spectrophotometer and the Martens photometer. The samples studied were furnished by various dealers and represent most of the glasses used for spectacle purposes. They include akopas, amber, amethyst, arkweld, blue, chlorophile, chromatic test, cobalt, Crookes' crown 1.5, electric euphos, fieuzal, hollauer, laboratory, lufel, noviold, noviweld, Pfund, rifleite, saniweld, smoke, welders. In most cases a number of shades are given. The table includes the company furnishing the sample, the color, the instrument used and the total transmission factor. Curves are given for 82 separate samples.

R. J. MONTGOMERY.

Glass compositions. Schnurpfel's Review for Glass Works, 3, 915, 917, 919 (1919).

| | Opal glass for blowing lbs. | Paste or strass glass lbs. | Plate glass | | Window glass without salt cake lbs. |
|-------------------------|-----------------------------------|-------------------------------------|-------------|------|--|
| | | | lbs. | lbs. | |
| Sand..... | 100 | 100 | 100 | 100 | 100 |
| Carbonate of soda..... | 28 | .. | 34 | 20 | 34 |
| Nitrate of soda..... | .. | .. | 2 | .. | .. |
| Sulphate of soda..... | .. | .. | .. | 21 | .. |
| Limestone..... | .. | .. | 30 | 32 | 34 |
| Arsenic..... | .. | 1 | 2 | 3 | 1½ |
| Feldspar..... | 25 | .. | .. | .. | .. |
| Fluorspar..... | 18 | .. | .. | .. | .. |
| Cryolite..... | 6 | .. | .. | .. | .. |
| Zinc oxide..... | 4 | .. | .. | .. | .. |
| Lead..... | .. | 100 | .. | .. | .. |
| Carbonate of potash.... | .. | 30 | .. | .. | .. |
| Nitrate of potash..... | 2 | 9 | .. | .. | .. |
| Borax..... | .. | 2 | .. | .. | .. |
| Cullet..... | .. | .. | 35 | 35 | .. |
| Charcoal..... | .. | .. | .. | 1 | .. |
| | | oz. | oz. | oz. | |
| Manganese..... | .. | 2-3 | 4 | 5 | .. |

R. J. MONTGOMERY.

Porcelain, glass-like, fusible. C. TOSTMANN, *Z. angew. Chem.*, 32, 320 (1920).—The author claims that the Rosenthal Company has done nothing new in working porcelain-like glass, since Victor Meyer in 1885 worked a hard porcelain tube of the Royal porcelain works as glass, bending same and drawing it out to a capillary tube as is done with glass.

H. G. SCHURECHT.

PATENTS

Glass-working machine. F. L. O. WADSWORTH. U. S. 1,326,235, Dec. 30, 1919. The flow of molten glass from an orifice in the bottom of a tank to molds positioned thereunder is automatically regulated in synchronism with the movement of the molds. These molds are positioned upon the ends of radial arms which rotate in a vertical plane about a horizontal axis.

Glass-drawing, electrically-heated bait for. L. S. SKELTON. U. S. 1,326,296, Dec. 30, 1919. This bait is in the form of a hollow annulus having a circular slot in the bottom thereof. When the bait is dipped into the molten glass preparatory to making the draw, some glass flows into the bait through the slot and solidifies therein, forming a neck whereby the cylinder is drawn. In order to prevent undue chilling of the bait and to keep its interior at a uniform temperature, an electric-heating coil is placed within the upper part of the bait.

Glass, method of and apparatus for drawing hollow. C. P. BYRNES. U. S. 1,326,571, Dec. 30, 1919. By the use of concentric baits a plurality of cylinders are drawn simultaneously, with consequent increases in output and decrease in the loss of glass in the pots. One or both of the cylinders may be distended during the initial stage of the draw to increase their diameter to that desired.

Mold-press (for glass). W. J. MILLER. U. S. 1,326,765, Dec. 30, 1919. This press is designed for the production of glass caskets. A quantity of molten glass is introduced into a mold chamber, a cap ring is held against the top of the mold chamber, and a core is forced downwardly into the mold chamber to mold the interior of the casket and force the molten glass up between the walls of mold and the core until it reaches the cap ring.

Glass-drawing apparatus. W. WESTBURY. U. S. 1,326,241, Dec. 30, 1919. Drawing pot and bait are supported by a framework which is movable over the glass furnace. In the top of this furnace are draw openings into which the pot is raised and protected from the intense radiation from the furnace during the draw.

(Glass) Pressing plunger mechanism (for). W. J. MILLER. U. S. 1,326,365, Dec. 30, 1919. In machines for pressing glass articles the plunger is mounted in such a manner that it may be adjusted and aligned to center it with the mold or molds as they are presented.

(Glass) Shear mechanism (for). W. A. LORENZ. U. S. 1,326,460, Dec. 30, 1919. This invention relates to shear blades used in severing molten glass into drops or gathers to form charges. These blades have reentrant V-shaped cutting edges which approach each other toward the apices of the Vs. The blades are of relatively thin sheet steel and thus absorb very little heat.

Glass. C. R. PEREGRINE. U. S. 1,327,569, Jan. 6, 1920. A relatively dense white glass which may be used with thin shades and powerful illuminating elements and which does not show the dead white color characteristic of milk glass, is made by adding to 1500 parts of clear glass batch containing zinc oxide, 260 parts of aluminum hydroxide and 151 parts of sodium silico-fluoride. Other aluminum containing compounds such as china clay and feldspar may be substituted for the aluminum hydroxide on the basis of aluminum present and other fluorides such as cryolite, sodium fluoride and fluorspar may be substituted for the sodium silico-fluoride on the basis of the fluorine present. Proportions may also be varied within limits.

G. E. MIDDLETON.

Whiteware and Porcelain

Bodies for spark plug insulators, preparation and composition of ceramic. A. V. BLEININGER. Report No. 53, National Advisory Committee for Aeronautics, pp. 25-31. In airplane engines the porcelain of the spark plugs is subjected to severe conditions, involving high temperatures,

sudden heating and cooling effects, and mechanical stresses. To be perfectly suited for the purpose, the material must remain a good electrical insulator at the maximum temperature reached, should not be subject to permanent volume changes, should possess constant thermal expansion, and must be strong and tough. Porcelains possessing such qualities have been developed in the Pittsburgh laboratory of the Bureau of Standards. The compositions in per cents of the best types are as follows: Porcelain, No. 152; Georgia kaolin, 10; Florida kaolin, 10; North Carolina kaolin, 10; Delaware kaolin, 10; Calcine No. 19, 40; Calcine No. 14, 20. The compositions in per cents of the calcines are: For calcine No. 19—kaolin, 70.20; alumina, 27.80; boric acid, 2.00. For calcine No. 14—kaolin, 56.00; magnesium carbonate (precipitated), 18.20; potters' flint, 25.80. For porcelain No. 194 the compositions in per cents are: Beryl, 35.0; Georgia kaolin, 12.5; Florida kaolin, 12.5; North Carolina kaolin, 12.5; Delaware kaolin, 12.5; potters' flint, 15.0.

A. J. LAMBERT.

Feldspar as a pottery material. H. F. STALEY. *Brick Clay Record*, 56, 335-338 (1920).—The feldspars may be roughly classed as potash feldspars, soda feldspars and lime feldspars. It is seldom that feldspars are found corresponding to these types as they are usually mixed with other feldspars and minerals. Potash feldspar occurs in two mineral forms, microcline and orthoclase, the former being the more common.

ANALYSES OF COMMERCIAL GROUND FELDSPARS

| S | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| SiO ₂ | 76.37 | 65.87 | 65.73 | 69.05 | 69.45 | 65.50 | 68.20 | 71.07 |
| Al ₂ O ₃ | 13.87 | 19.10 | 19.28 | 17.40 | 16.76 | 21.17 | 18.17 | 16.23 |
| | (a) | (a) | (a) | | | | | |
| Fe ₂ O ₃..... | ..... | ..... | ..... | .15 | 0.20 | 0.18 | 0.66 | 0.53 |
| CaO..... | 0.26 | 0.20 | 0.22 | 0.12 | 0.45 | 0.87 | 0.38 | 0.43 |
| MgO..... | 0.00 | ..... | ..... | ..... | 0.45 | 1.40 | 0.26 | 0.24 |
| K ₂ O..... | 5.24 | 12.24 | 10.26 | 10.03 | 9.80 | 8.98 | 10.18 | 8.24 |
| Na ₂ O..... | 3.74 | 2.56 | 4.08 | 2.97 | 2.60 | 1.00 | 2.60 | 2.98 |
| Loss on ignit... | 0.30 | 0.64 | 0.48 | ..... | 0.28 | 0.15 | 0.59 | 0.39 |

(a) Including small amounts of iron oxides.

1. Ground feldspar, No. 3 grade from near Bedford, N. Y. 2. Ground feldspar, No. 1 grade from Bedford, Ontario. 3. Ground feldspar, No. 1 grade from Auburn, Me. 4. Pennsylvania ground feldspar. 5. No. 2 potash feldspar from near Bedford, N. Y. 6. Soda feldspar. 7 and 8. No. 1 grade Maine feldspar showing maximum variations in five shipments.

The most practical solution of the feldspar problem for potters may be stated as follows: 1. The purchase of no feldspar of grade poorer than No. 2, from reputable producers, and insistence that the material be furnished up to grade. 2. The use of at least two brands of feldspar in each mix, the amount used of each brand being taken from two different shipments. 3.

Thorough testing in trial melts of each new shipment of feldspar to determine what change, if any, should be made in the mix to accommodate it to the new feldspar. Chemical analysis are not satisfactory for judging feldspar. Of the several minerals proposed as substitutes for feldspar, Cornwall stone is the most satisfactory. Its effects in pottery bodies are somewhat different from those of feldspar.

H. G. SCHURECHT.

Filter presses, clothless. *Keram.Rundschau*, 28, 30 (1920).—The German Ceramic Society awarded the first prize for inventing substitutes in filter presses to S. Schneider of Hennigsdorf for his tin plate patented filter press. It consists of a large vessel in which are stacked a large number of tin plates having a hollow center. These ring-like plates are pressed together with bolts. The slip is passed in the center of rings under a pressure and the liquid forced through very small ring-shaped spaces between the plates, leaving the filtered mass in the hollow center. The charge is removed from the apparatus automatically so the process is continuous. If the filter becomes clogged it can be easily cleaned by passing water through the same. The second prize was given to A. Zöllner, who developed a special paper which can be used successfully as a substitute for filter cloth. The third prize was given to B. Schwarz who invented porous plates to be used in the ordinary filter press. An inner plate has very coarse pores while the outer has extremely fine pores. A fourth prize was given to E. Rosenthal who developed a dry mixing process without using filter presses. The constituents are ground very fine and mixed thoroughly in a mixing machine, thereby doing away with the filter press.

H. G. SCHURECHT.

Pottery manufacture, some unestimated losses in. *Pottery Gaz.*, 512, 222-223 (1920).—Dr. J. W. Mellor and others. Care in the storage of clays is emphasized. In some cases specks in ware were traced to a rusty iron gas bracket in the storeroom which upon bumping caused a shower of rust to fall in the clay. Inefficiency of engines and boilers in potteries is common. In one case most of the men in a pottery were idle because there was not enough steam generated to run a pug mill. It was impossible to work the engine faster than 27 r. p. m. Upon consulting a competent engineer it was speeded up to 140 r. p. m. Bad stoking is another source of loss. Sending black clouds of smoke through the chimney is an unnecessary waste of fuel. At fully one-half of the potteries there is no attempt to make use of exhaust steam, although this is the best water for boilers. When a load of clay is delivered the floor should be cleaned before dumping, thus avoiding big losses, due to dirty clay. Well-regulated factories use $\frac{3}{10}$ -inch wads, while in most of the factories $\frac{7}{10}$ -inch wad clay is used, which is too thick. The weight of clay used in the latter case is five times more than was used in the first case and as a rule the loss due to "dirty" ware is increased. Thick wads also cause an increase in sagger losses. A saving of £1,000 may be obtained in one year in many plants by regulating the size of wad used. Gold otherwise lost in decorating processes may be recovered. Covering papers and rags

from the turn-tables and benches of the decorators are collected weekly. The gold is recovered by burning the paper and rags and treating the ash with a flux and oxidizing agent. An iron cauldron about 19 in. in diameter fitted with a stout wire grating about $1\frac{1}{2}$ inch mesh has been found to constitute a useful grate. On the top of this was fitted an iron cylinder with a lid. The dust remaining in the cauldron after the burning was collected and mixed with a flux and oxidizing agent as follows: Ash, 12 oz.; borax glass, 10 oz.; potassium nitrate, 2 oz. Borax glass is preferable to borax crystals and some people recommend covering the mixture with salt before firing in a kiln. A nugget of gold will be left in the bottom of the crucible. It is advisable to encase the crucible containing the mixture with an earthenware lining for safety.

H. G. SCHURECHT.

PATENTS

Pulldown for potteries. G. LOWRY. U. S. 1,326,756. Dec. 30, 1919. The vertical arm which carries the shoe passes through rollers held on a horizontal arm. The vertical arm is curved in such a manner that the shoe descends into the center of the mold, but is then shifted into operative position at the side. In withdrawing the shoe it is similarly automatically moved to the center of the mold and then raised.

G. E. MIDDLETON.

Cement and Lime

Effect of Fineness of Cement. DUFF A. ABRAMS. *Proceedings of A. S. T. M.*, 19, Part II, pp. 328-424.—An investigation of the effect of fineness of cement has been under way for the past four years, through the coöperation of the Portland Cement Association and Lewis Institute at the Structural Materials Research Laboratory. The Portland cements used were from seven commercial mills. These plants represent the principal cement-producing districts east of the Mississippi River. Fifty-one different samples of cement were used. The cements were ground at the mill to four to seven degrees of fineness, which gave residues ranging from 2 to 43 per cent on the standard No. 200 sieve. In general, the aggregate consisted of sand and pebbles; in one series blast-furnace slag and a light-weight aggregate consisting of burnt shale were used. This report covers compression tests on 6125 6 × 12-in. concrete cylinders, 9000 compression and tension tests of mortar, and several thousand miscellaneous tests. Strength tests of concrete and mortar were made at ages of 7 days to one year. Conclusions from the tests: (1) There is no necessary relation between the strength of concrete and the fineness of the cement, if different cements are considered. (2) In general, the strength of concrete increases with the fineness of a given lot of cement, for all mixes, consistencies, gradings of the aggregate, and ages of concrete. The cements with residues lower than about 10 per cent were inclined to give erratic results in the strength tests. (3) For residues higher than 10 per cent the strength of concrete varies approximately inversely as the residue of the No. 200 sieve. (4) Fine grinding of cement is more effective in increasing the strength of lean mixtures than rich ones. (5) Fine grinding of cement is

more effective in increasing the strength of concrete at 7 days than at ages of 28 days to 1 year. (6) For the usual range of consistencies the effect of fineness of cement is independent of the consistency of the concrete. The rate of increase in strength with fineness is lowered for very wet mixtures. (7) Ordinary concrete mixtures at 28 days show an increase in strength of about 2 per cent for 1 per cent reduction in the residue of the cement on the No. 200 sieve. At 7 days, 3 months and 1 year the corresponding increases in strength are about 2.5, 1.7 and 1.4 per cent. (8) The decreased benefit of fine grinding of cement with the age of the concrete does not bear out accepted opinion that the coarser particles of cement do not hydrate, but indicates that the principal result of finer grinding is to hasten the early hardening of the concrete. (9) For the richer mixtures and the consistency necessary for building construction, the fineness of the cement has no appreciable effect on the workability of concrete as determined by the "slump" test. For leaner mixtures and wetter consistencies, the finer cements showed a somewhat greater "slump" than the coarser cements. (10) The normal consistency of cement is increased with fineness of grinding. About 0.1 per cent of water (in terms of the weight of the cement) must be added for each 1 per cent reduction in residue on the No. 200 sieve. (11) The time of setting of the cement is shortened with finer grinding. (12) The unit weight of cement decreases with fineness. For the cements used in these tests the weight varied from 76 (residue of 2.4 per cent) to 108 lbs. per cu. ft. (residue 43.3 per cent). For the usual range in fineness the weight is lowered about $\frac{3}{4}$ lb. per cu. ft. for each 1 per cent reduction in the residue on the No. 200 sieve. (13) In using 94 lbs. per cu. ft. as a uniform basis for proportioning the cements in these tests, the actual volume of cement in a batch of the same mix varies about 35 per cent. If the mixtures had been proportioned in a manner that would have given a uniform volume of cement, the resulting concrete strength would not have been so favorable to the finer cements. (14) The fineness of cement has no appreciable effect on the yield or density of concrete. (15) Concrete of all mixes and consistencies showed expansion in damp sand or water storage and contraction in air. (16) The change in length of concrete specimens stored in air or water is independent of the fineness of the cement and the consistency of the concrete. The lean concretes are slightly less affected than the rich mixtures. (17) The type of aggregate has little or no influence on the relative effect of fineness of cement on the strength of concrete. (18) The tests included in this report show an intimate relation between the strength of the concrete and the water-ratio of the mixture. The lower the water-ratio (so long as the concrete is plastic and the aggregate not too coarse) the higher the strength, and *vice versa*. This confirms the results of other concrete tests made in this laboratory. Increasing the quantity of cement in a given mixture enables us to secure a concrete of equal workability with a lower water-ratio, hence a higher strength. (19) In ordinary concrete mixtures (say 1 : 5 to 1 : 4, requiring 20 to 25 per cent cement by volume) increasing the cement content by 1 per cent (to 20.2 per cent for a 1 : 5 mix)

gives an increase in strength of about 1 per cent. (20) One per cent increase in cement is more effective in increasing the strength of concrete in lean than in rich mixtures. (21) One per cent increase in cement is somewhat more effective in increasing the early strength of concrete than at later periods. (22) The effect of increasing the quantity of cement is independent of the consistency of the concrete. (23) Tension tests of briquettes do not give a correct measure of the relative merits of different cements as determined by compression tests of mortar and concrete.

A. J. LAMBERT.

Cements producing quick-hardening concrete. P. H. BATES. *Proceedings A. S. T. M.*, 19, Part II, 425-438.—There have been prepared at the Pittsburgh Branch of the Bureau of Standards certain cements which have the property of hardening very rapidly. These were made in a manner no different from that used in making Portland cement. Their composition differed very materially from the composition of the latter, in that they were composed very largely of lime and alumina. These calcium aluminates, when they are very high in alumina, do not have a very marked rapid initial set, but do harden very quickly and therefore produce high early strengths. Some of the maximum strengths were 3145 lbs. per sq. in. for 1 : 6 gravel concrete tested in the form of a 6 × 12-in. cylinder at the end of 24 hours, 6010 sq. in. at the end of seven days, and 8220 lbs. per sq. in. at the end of one year. "Sorel cements" are those produced by gaging light calcined magnesia with magnesium chloride solution. Such a cement develops in 24 hours a strength approximately equivalent to that developed at the end of seven days by a similar concrete made with Portland cement. Both of these cements commend themselves for certain special uses, where a quick-hardening concrete of high strength is desired. Neither would be desirable where subjected to the continued action of water. The Sorel cement alone is on the market at the present time.

A. J. LAMBERT.

Cements for spark-plug electrodes. H. F. STALEY. *Bur. Standards, Tech. Paper* 155.

A. J. LAMBERT.

PATENTS

Cementing material obtained from greensand. H. W. CHARLTON. U. S. 1,327,145, Jan. 6, 1920. A greenish or brownish white material containing silicates of iron, calcium and aluminum, is obtained by digesting greensand with lime. This material when freshly made is plastic and self-hardening and is capable when heated with steam of undergoing a still further hardening process.

G. E. MIDDLETON.

Abrasives

PATENTS

Abrasive wheel, lubricating, and method of making it. I. L. KATZENSTEIN. U. S. 1,325,503, Dec. 16, 1919. The abrasive wheel is heated to a temperature

above that of the filler to be used and immersed in a molten bath of this filler to impregnate the pores of the wheel. The wheel is then removed, and while the filler is still molten, rotated to remove the excess centrifugally. A combination of paraffin and rosin is given as a specific example of the filler used.

Abrasive tool and process of making it. C. R. KING. U. S. 1,325,504, Dec. 16, 1919. A so-called "elastic" abrasive wheel or tool comprising abrasive grains bonded by a bond comprising shellac and plaster of Paris, the proportions being 12-30 per cent shellac, 3-20 per cent plaster of Paris, and the rest abrasive.

G. E. MIDDLETON.

ACTIVITIES OF THE SOCIETY

Important Actions Taken by the Board of Trustees at Meetings Held during the Annual Meeting at Philadelphia, February 23-26, 1920

It was voted to recommend to the Committee on Publications that 2200 copies of each issue of the JOURNAL be printed in 1920.

It was voted that the reinstatement of German members be put upon the same basis as that of other members in arrears.

It was voted that the Secretary be instructed to send the JOURNAL, beginning with Vol. I, to the library of Louvain, Belgium, and also a copy of Branner's "Bibliography of the Ceramic Arts."

It was voted that President Stull should recommend to the new President the appointment of Colonel Orton as chairman of the committee on the visit of the English Ceramic Society.

It was voted that members in arrears for two years should be communicated with once more, and, if dues then remained unpaid, the members should be dropped from the rolls of the Society.

It was voted that notice be given of a change in rule pending, to the effect first, that the annual dues of Active and Associate Members, respectively, shall be fixed by the Board of Trustees but shall not exceed ten dollars, the privileges of membership to begin upon payment of the annual dues; second, that the annual dues of Active, Associate, and Corporation Members shall be due and payable on January first each year.

One-hundred and eighteen Associates were elevated to Active Membership.

It was voted to authorize the Treasurer to invest \$5000 in government bonds.

It was voted that one copy of the Collective Index to the Transactions should be available to each member of the Society at a charge of fifty cents and that a letter to this effect be sent to all members. Also that the price of the Index to non-members shall be \$1.50.

It was voted that Chas. F. Binns be appointed Secretary of the Society for the fiscal year, beginning January 1, 1920, at a salary of \$1000 per annum.

It was voted that Norah W. Binns be re-appointed Assistant Secretary for the fiscal year, beginning January 1, 1920, at a salary of \$1200 per annum.

ASSOCIATE MEMBERS ELEVATED TO ACTIVE MEMBERSHIP, FEB. 26, 1920

| | | |
|-----------------------|-----------------|-----------------|
| Allen, F. B. | Back, Robert | Bellamy, H. T. |
| Applegate, D. H., Jr. | Balmert, R. M. | Binns, Norah W. |
| Arbogast, F. J. | Balz, Geo. A. | Blackmer, E. L. |
| Ayres, E. B. | Bartells, H. H. | Blewett, J. B. |

| | | |
|--------------------|--------------------|---------------------|
| Boughcy, Joseph | Gates, M. E. | McBean, Atholl |
| Bowman, O. O., 2nd | Geiger, Chas. F. | McCann, J. S. |
| Brewster, Robert | Gibbs, A. E. | McCoy, Wm. |
| Breyer, F. G. | Gladding, A. L. | McDanel, W. W. |
| Brower, Fred | Grant, De Forest | McVay, T. M. |
| Brown, L. K. | Green, J. L. | Oudin, C. P. |
| Brownlee, W. K. | Haley, M. A. | Paterson, Alexander |
| Burroughs, F. H. | Hall, C. A. | Pettinos, G. F. |
| Butterworth, F. W. | Hardy, I. E. | Powell, W. H. |
| Chency, M. B. | Harker, H. N. | Purington, B. S. |
| Chormann, O. I. | Hasburg, J. W. | Rainey, L. B. |
| Christmann, C. E. | Hastings, F. N. | Rand, C. C. |
| Claudon, C. F. | Hatton, R. D. | Reed, Henry M. |
| Cooke, R. D. | Ittner, Warren | Rice, B. A. |
| Coors, H. F. | Johnston, John | Rodgers, Eben |
| Covan, H. E. | Keplinger, R. B. | Roessler, Franz |
| Crane, C. W. | Kimble, H. K. | Ross, D. W. |
| Davenport, R. W. | Kleymeyer, H. C. | Saunders, W. E. |
| Dean, C. A. | Knollman, H. J. | Schory, V. S. |
| DeVoe, Chas. H. | Krick, G. M. | Sinclair, Herbert |
| Dickey, Fred L. | Laird, J. S. | Smith, W. L., Jr. |
| Dinsmore, B. B. | Larkin, P. G. | Springe, Otto |
| Dobbins, T. M. | Layman, F. E. | Sproat, Ira |
| Dunn, F. B. | Lillibridge, H. D. | Stanger, Frederick |
| Ebinger, D. H. | Linder, C. S. | Stevens, D. F. |
| Edgar, D. R. | Longenecker, H. L. | Stowe, C. B. |
| Eskesen, B. K. | Lucas, H. J. | Tefft, C. F. |
| Fisher, D. J. | Maddock, H. E. | Thompson, D. D. |
| Fisher, Geo. P. | Malm, A. T. | Tilton, Earl |
| Forst, A. D. | Maltby, Alfred | Van Schoick, E. H. |
| Frazer, W. B. | Martens, Paul | Vodrey, W. E. |
| Fraunfelter, C. D. | Martz, J. A. | Whitaker, F. A. |
| Freese, H. H. | Miner, H. S. | Whitehead, Fred |
| Fulweiler, W. H. | Mueller, Theo. | Whitner, J. D. |
| Gahris, W. I. | Munshaw, L. M. | Wright, J. W. |
| Gates, A. W. | | |

Notice

The Edgemont Feldspar Company is no longer in the feldspar business, and persons holding the Directory of Dealers should delete the name.

New Members Received during March

Resident Associate

Albery, D. F., Chemist, Federal Terra Cotta Co., Woodbridge, N. J.
 Amsler, W. O., D. Sc., President, Amsler-Morton Co., Pittsburgh, Pa.

- Barlow, Alfred, Superintendent, Golding Sons Co., Wilmington, Del.
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- Brown, Leslie, Lenox, Inc., Trenton, N. J.
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- Foltz, Andrew, President, Lambertville Pottery Co., Lambertville, N. J.
- Frantz, Samuel G., Crossett Lumber Co., Crossett, Ark.
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- George, W. C., Vice-President, W. S. George Pottery Co., East Palestine, Ohio.
- Godejohn, W. F., Laclede-Christy Clay Products Co., St. Louis, Mo.
- Goodman, A. H., Sales Engineer, Blaw-Knox Co., Pittsburgh, Pa.
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- Trood, Samuel, Vice-President and General Manager, U. S. Sherardizing Co., New Castle, Pa.
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Gillinder Bros., Port Jervis, N. Y.

Philadelphia Drying Machinery Co., Philadelphia, Pa.

Reliance Firebrick & Pottery Co., Ltd., Chanch, Barakar P. O., East India Railway, India.

Standard Sanitary Mfg. Co., Bessemer Bldg., Pittsburgh, Pa.

Necrology

FRITZ WAGNER.—In the passing of Fritz Wagner the terra cotta industry has suffered a great loss. He was a remarkable man, always resourceful, always vigorous, always just. He possessed a wonderful personality which, coupled with his thorough knowledge of the architectural profession as well as his own particular line, assured him lasting place in the profession.

For many years he was a welcomed adviser on material and construction in the best architects' offices, thereby doing more to increase the use of his material than was ever done by any man or group of men. He always stood strong for the best possible material and he always stood by his material, saw that it was right and that it was used right. His acquaintance among the architects was very wide and they, very properly, had absolute confidence in him. He has left the mark of his individuality indelibly impressed on buildings all over the United States, and these shall stand as a monument to his intelligence and sterling integrity.

In more than thirty years of closest competition, I can recall no unkind or questionable act between us. I know him as few others did and he won my admiration, esteem and love, and I sincerely mourn his passing.

WM. D. GATES.

MR. IDRIS NELSON.—After graduating from the University of Illinois, Mr. Nelson entered the service of the Purington Paving Brick Company as a ceramic engineer in the Fall of 1913. A year later he returned to the University of Illinois and took a graduate course in ceramics, returning to the employ of the same company. He rose to the position of Assistant General Superintendent. He died January 27th, 1920, of pneumonia, after an illness of about a week.

Mr. Nelson was a very efficient and capable engineer and had a bright future. He was a member of the American Ceramic Society, Masonic Fraternity and Elks Lodge. Mr. Nelson was married in June, 1917.

JOURNAL **OF THE** **AMERICAN CERAMIC SOCIETY**

A monthly journal devoted to the arts and sciences related to the silicate industries.

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May, 1920

No. 5

EDITORIALS

SUSTAINED INTEREST IN CERAMICS

It was the writer's pleasure to attend the meeting of the Northern Ohio Section of the American Ceramic Society held at Detroit on April 5th and also the meeting of the Pittsburgh District Section held in Pittsburgh on April 20th, and the spirit of friendly professional interest and coöperation which prevailed at both meetings convincingly indicated the permanent interest which is sustained between the annual meetings or conventions of the Society as a whole.

At the Detroit meeting twenty-five men gathered for conference and discussion, a group as large as some of the very early annual meetings of the Society and of many of the summer meetings. There were men present from Detroit, Flint and Kalamazoo, Mich., Cleveland and Toledo, Ohio, Natrona and Sharon, Pa., Chicago, Ill., and Schenectady, N. Y.

At the Pittsburgh meeting sixty-five men were present at the afternoon session, a number equalling the attendance at the annual conventions up to a very few years ago and equal to the attendance at the summer meetings even up to the present time. At this gathering men were present from Pittsburgh and Beaver Falls, Pa., Columbus and East Liverpool, O., New York City and Schenectady, N. Y., Detroit, Mich., Washington, D. C., etc.

Accounts of these meetings will be found in the usual place in the JOURNAL, but the writer wishes to point out the fact of established continuity of professional interest among the members of the American Ceramic Society. At these inter-conven-

tion group meetings there is naturally less formality in papers and discussions than in the formal annual convention; but the opportunities for personal contact and growth of friendship is greater, and the section meetings will prove of greater and greater value to the individual as time goes on and will promote to a greater degree than any other agency the professional pride and loyalty so essential to the progress of any technical society.

A QUESTION IN REGARD TO ABSTRACTS

In general there are two kinds of abstracts. One gives simply a short description of the article abstracted and makes it necessary for the reader to refer to the original paper for the data presented by the author; the other gives the essential data of the paper. Abstracts of the latter class are necessarily longer than those of the first. Since, as a rule, a large variety of technical journals is not available to our readers, we have felt it incumbent on us to give abstracts of the second class.

This has proven rather expensive, for it costs us about three dollars a page more to secure and print abstracts than to print original papers. Moreover, the printing of abstracts reduces the amount of space that can be devoted to original papers. The question has arisen, therefore, whether it would be desirable to print shorter abstracts and fewer pages of abstracts in each issue of the JOURNAL and more pages of original papers. The JOURNAL is published solely for the benefit of the members of the Society, and the editor would like to have an expression of opinion on this subject from every member who cares anything about the character of the JOURNAL.

ORIGINAL PAPERS AND DISCUSSIONS

ELUTRIATION TESTS ON AMERICAN KAOLINS¹

BY H. G. SCHURECHT

Introduction

The classifications of clays according to grain size is important in the testing of clays as many physical properties, such as plasticity, dry strength and shrinkage, are to a limited degree functions of the size of grain. The ease of vitrification and fusion are also influenced by fineness of grain. For example, it was found that a substitution of the comparatively coarse North Carolina kaolin for the finer grained English china clay in pottery bodies produces an extremely porous product as compared to the more vitreous ware obtained when the English clay is used. A more complete knowledge of the fineness of our domestic kaolins would be valuable to the potter attempting to use domestic clays in the place of foreign clays.

Chemical analysis and microscopic examination of the different portions separated by elutriation are also important and will in many cases explain differences in the behavior of clays which have the same degree of fineness. This paper, however, is limited to the elutriation of clays with precautions necessary to obtain accurate results with the Schulze elutriator and with results obtained on some domestic kaolins.

Sieve Analysis

The material coarser than 0.074 mm. can easily be separated into different sizes by means of screens. Five hundred grams of sample are crushed to pass a 4-mesh sieve after which the sample is thoroughly blunged with 1000 cc. of distilled water in

¹ By permission of the Director, U. S. Bureau of Mines.

a two-quart "Daisy" churn. The clay is then separated into the following classes by wet screening:

> 20 mesh
20- 65 mesh
65-100 mesh
100-200 mesh

For the above tests, standard Tyler screens were used having the following sizes of openings:

| Mesh | Size of opening | |
|------|-----------------|-------------|
| | Inches | Millimeters |
| 20 | 0.0328 | 0.833 |
| 65 | .0082 | .208 |
| 100 | .0038 | .147 |
| 200 | .0029 | .074 |

Elutriation Analysis

Description of Apparatus.—Figures 1 and 2 show the modified Schulze apparatus as used. (1) Shows a gauge to regulate the flow of water; (2) indicates the glass funnel for feeding clay into the elutriator drop by drop; (3) a separatory funnel to introduce ammonium hydroxide into the feed water; (4) distilled water reservoir; (5) overflow tank with a constant water level; (6) can 1, (7) can 2, (8) can 3, (9) can 4 and (10) a jar to catch the overflow from can 4.

The cans are gold plated to prevent corrosion of the copper and to reduce the tendency of the clay to adhere to the metal sides.

The overflow in this apparatus passes over the rim of the cans and is caught in a launder which extends around the outside. In this respect this apparatus differs considerably from the original Schulze elutriator in which the overflow is carried to the next can through a spout in the side of the vessel. The spout tends to form a channel of water which flows comparatively rapid. Allowing the overflow to pass evenly over the sides of rim of the can would tend to overcome this source of error, but owing to the surface tension and adhesion, and the slow rate of flow of the water, the liquid does not overflow evenly in the larger cans. However, it can be made to pass over in four or more places by fastening copper clips on the rims of the cans

which produces a more uniform flow than is obtained by using a side spout as an outlet.

Standardization of the Apparatus.—It is necessary to carefully measure the cross-sectional area of each can. This may be done with calipers or by filling the cone-shaped portions of the can with water and then adding a known volume of water to the vessel.

Elutriation Cans.

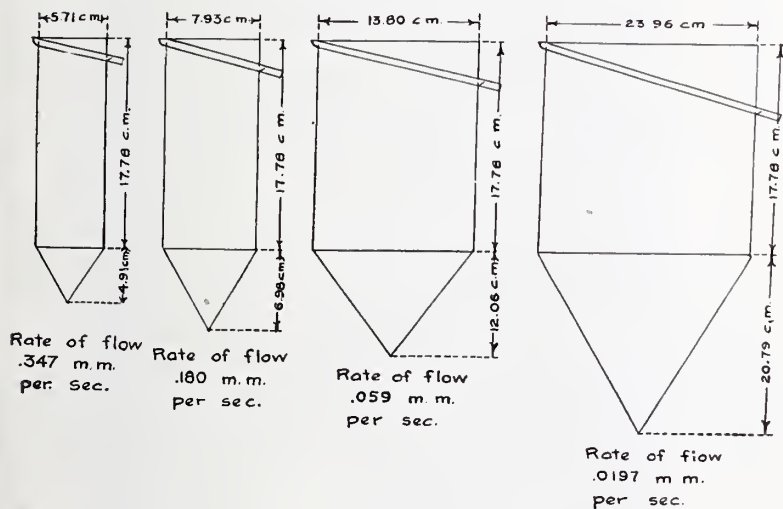


FIG. 1.

The height of the volume of water is carefully measured in the elutriation can and the cross-section obtained as follows:

$$A = \frac{V}{H}$$

A = cross-sectional area. V = volume of water. H = height of water.

Having determined the cross-sectional area of the cans, it is now possible to regulate the velocity of flow as follows:

$$R = \frac{V}{A}$$

V = volume in cu. mm. per sec. A = cross-sectional area of can in sq. mm. R = velocity of flow in mm. per sec.

It is desirable to regulate the apparatus so that can 2 will have a velocity of 0.18 mm. per second as this velocity separates clay-like substance (*i. e.*, material under 0.010 mm. in diameter) from the coarser silt and sand. For example, to determine the volume of flow in order to produce a velocity of 0.180 mm. per

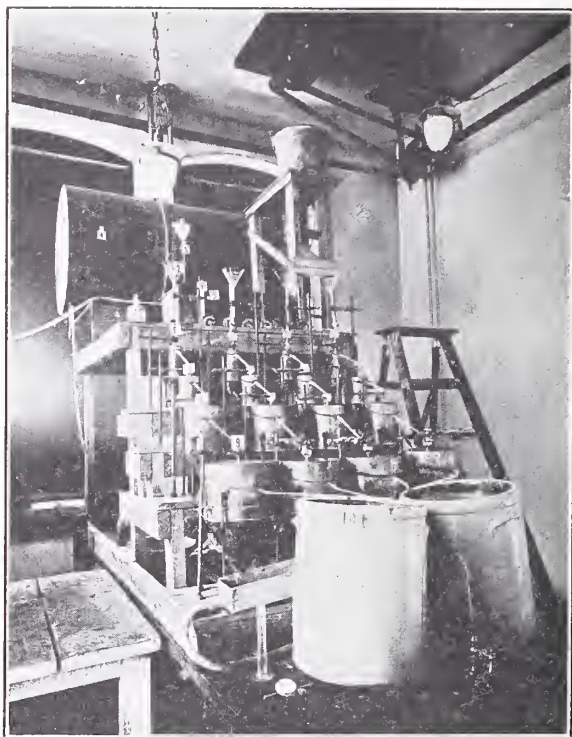


FIG. 2 —Elutriator.

second in can 2 which has a cross-sectional area of 4938.03 sq. mm.

$$0.18 = \frac{v}{4938.03}$$

$$v = 888.85 \text{ cu. mm. per sec.}$$

$$53.33 \text{ cc. per min.}$$

This velocity was used in the work, and the following values were obtained for each can:

| | Can 1 | Can 2 | Can 3 | Can 4 |
|------------|-------|-------|-------|---------------------|
| Velocity = | 0.347 | 0.180 | 0.059 | 0.0197 mm. per sec. |

Relation between Velocity of Flow and Diameter of Particles.—Schöne¹ suggested the following empirical formula to calculate the diameter of grains carried off by a given velocity which was found fairly accurate in practice.

$$D = 0.0314 V^{0.636}.$$

V = velocity of flow in mm. per sec.

D = maximum diameter of spherical grain-specific gravity 2.65.

For the velocities used in this investigation the diameter would correspond to those given below:

$$\text{Velocity} = 0.371 \quad 0.180 \quad 0.059 \quad 0.0197 \text{ mm. per sec.}$$

$$\text{Diameter} = .0160 \quad .0105 \quad .0052 \quad .0026 \text{ mm.}$$

Where the specific gravity is other than 2.65 the formula becomes

$$D = 0.0518 \frac{V^{0.636}}{S - 1}$$

where S = specific gravity of the substance.

The shape of the particle is also important. For example, Rittinger found that for coarse particles the velocity of settle was

$$C \sqrt{D(S - 1)}$$

where C is a constant depending upon the shape of particles and S represents the specific gravity of the substance. For different shapes C varied as follows:

$C = 2.73$ for roundish grains.

$C = 2.37$ for long, narrow grains.

$C = 1.97$ for flat grains.

$C = 2.44$ for average grains.

We would, therefore, expect large particles of mica, which are flat, to be separated with comparatively small particles of clay which was actually found to be the case.

Clays classified by screening and elutriation may be divided

¹ Schöne, E., "Ueber Schlamm-analyse und einen neuen Schlammapparat," Berlin, 1867.

into different grades according to their size of grain as was suggested by Seger and Mellor¹ as follows:

Stones—particles above 12.7 mm.

Gravel—particles between 1.27 and 12.7 mm.

Sand—particles between 0.107 and 1.27 mm.

Grit—particles between 0.063 and 0.197 mm.

Silt—particles between 0.010 and 0.063 mm.

Dust or claylike substances—particles below 0.010 mm.

Deflocculation of Kaolin.—The material passing through a 200-mesh sieve is used for elutriation. It is first necessary to deflocculate the particles which are clotted, otherwise a clot or aggregate of fine grains will behave like a large grain and settle in one of the first cans of the elutriator. The aggregates may be separated by thorough deflocculation with NaOH. The point of maximum dispersion is determined by adding 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, 0.14, 0.16, 0.18, 0.20, 0.22, 0.24, 0.26, 0.28 and 0.30 per cent of NaOH to slips containing 100 grams of dry clay and 400 grams of distilled water and determining the point of minimum viscosity. This is done with a flow viscosimeter² in the customary manner.

Manipulation of Elutriator.—Before a sample is introduced into the elutriator it is advisable to reduce the rate of flow of the elutriator to about one-third of that desired, which is about 17.77 cc. per minute for the elutriator used in this work. Fifty grams of deflocculated clay are slowly introduced into the apparatus, drop by drop, by means of funnels (2) shown in figure 2. During the period in which the clay is being fed into the elutriator, the velocity of flow should never exceed two-thirds of the maximum, for if the maximum velocity is employed with all of the sample in can 1, the diameter of the material carried away from this can would be too large. The specific gravity of the slip in can 1 should be as close to unity as possible before the

¹ Mellor, J. W., "Jackson's and Purdy's Surface Factors," *Trans. Eng. Ceram. Soc.*, 9, 106 (1909-10).

² Bleining, A. V. and Hornung, M. R., "Notes on Casting," *Ibid.*, 17, 330-335 (1915).

maximum flow is used. The diameter of the particles carried away would be approximately as follows:

$$D = 0.0518 \frac{V^{0.636}}{S - L_s}$$

where L_s is the specific gravity of the slip.

As elutriation proceeds, considerable NaOH is washed away by the overflow causing an increase in viscosity by flocculation. In order to remedy this evil a dilute solution of ammonium hydroxide is slowly added to the feed water.

In the course of elutriation it was found that fine clay settled along the sides of the cone in the bottom of the elutriator cans and the water coming from the thistle tubes flowed over it as is shown in the sketch (figure 2). It was found almost impossible to get good checks even after a week's time. To overcome this error it was found necessary to stir the residues deposited at intervals. This is done once each day for three days. The flow in the elutriator is stopped, and the clay is allowed to settle for at least 30 minutes, and two inches of water are siphoned from the top of each can. Air is gently forced through the tubes for one minute, which thoroughly stirs up the fine clay. At the end of three days, when the overflow from the last can becomes clear, the residues are removed from the cans, dried and weighed.

It is advisable to let the water from the preceding cans flow against the sides of the thistle tubes of the succeeding cans to prevent the entrapping of air in the tubes which is carried down to the bottom of the can and rising rapidly to the surface introduces a source of error.

The grain size of each residue is measured under a microscope by taking the average of at least 60 grains.

Calculation of Results.—For calculating the average size of grain the following formula¹ was used where d_1 represents the maximum diameter and d_2 the minimum.

$$D = \sqrt[3]{\frac{(d_1 + d_2)(d_1^2 + d_2^2)}{4}}$$

¹ Mellor, J. W., *Loc. cit.*, p. 107.

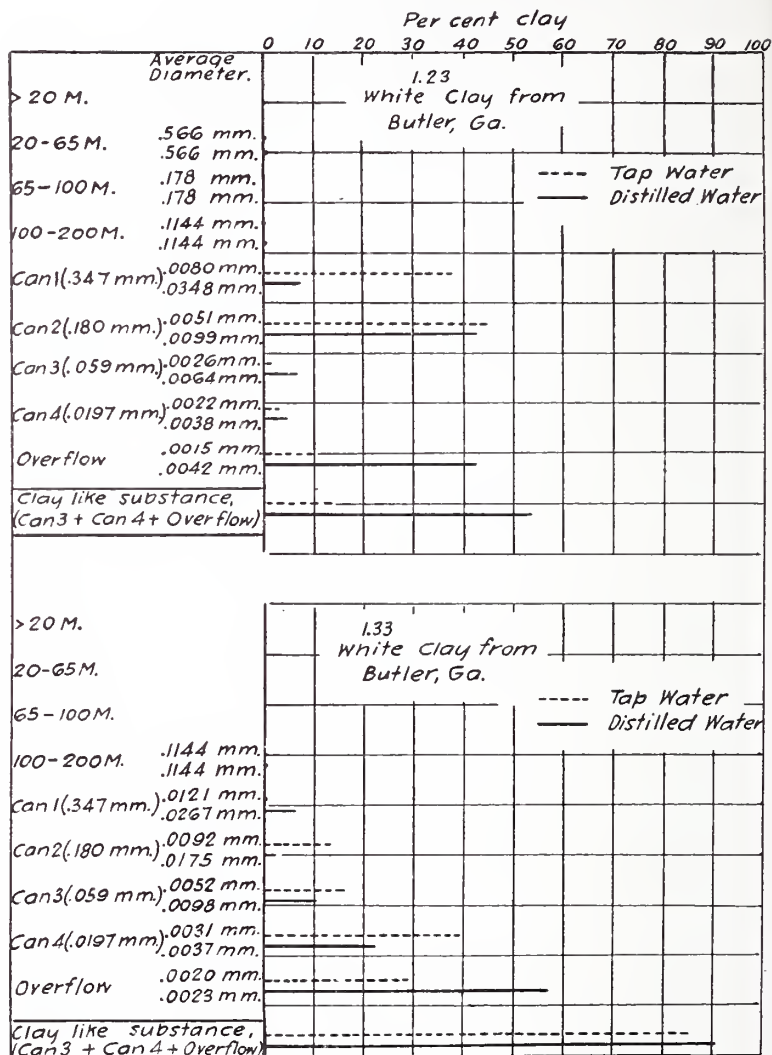


FIG. 3.—A comparison of tap water versus distilled water in elutriation tests.

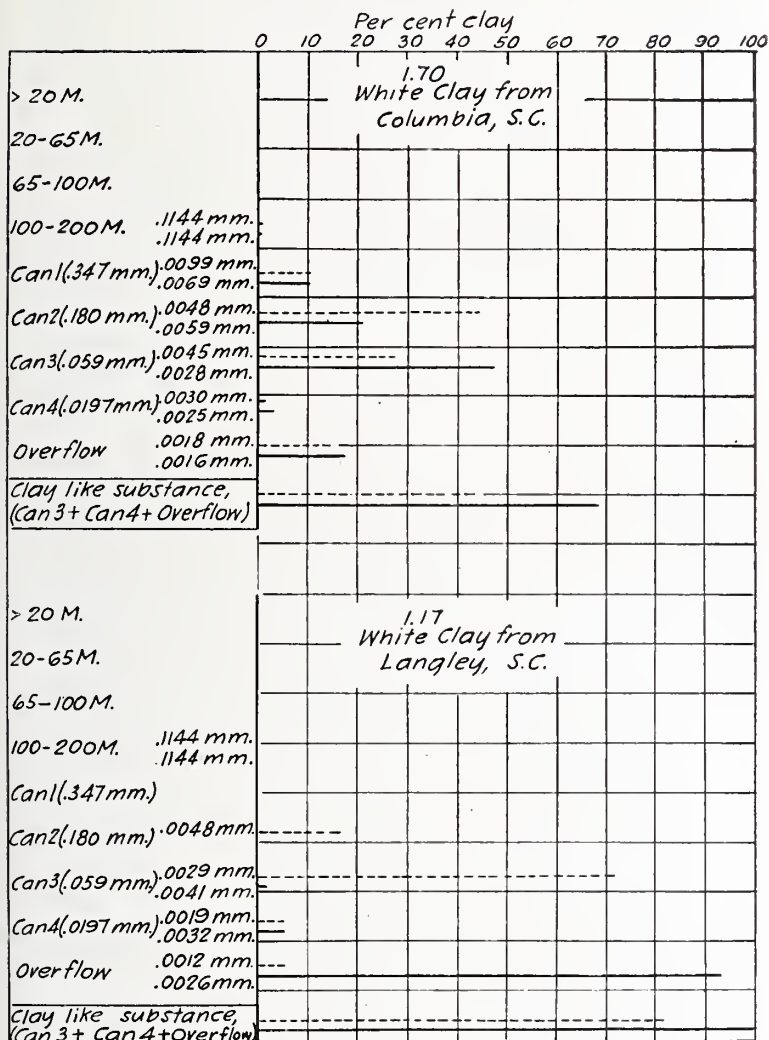
FIG. 4.—A comparison of tap water *versus* distilled water in elutriation tests.

TABLE 1.—RESULTS OBTAINED BY USING COLUMBUS TAP WATER AND DISTILLED WATER IN THE ELUTRIATION OF KAOLINS

| T. W.—Tap Water | | | | D. W.—Distilled Water | | | | | | | |
|-----------------|-------|-----------|------------|------------------------------|------------------------------|------------------------------|-------------------------------|----------|--------------------------------|----------------------------|----------|
| Sample | 20 M. | 65-100 M. | 100-200 M. | Can 1 Veloc. 0.347 mm. | Can 2 Veloc. 0.180 mm. | Can 3 Veloc. 0.059 mm. | Can 4 Veloc. 0.0197 mm. | Overflow | Can 3 + Can 4 + Overflow | Total surface factor | |
| 1.23 | | | | | | | | | | | |
| Butler, Ga. | | | | | | | | | | | |
| Per cent | | | | | | | | | | | |
| T. W..... | 0 | 0.12 | 0.03 | 0.97 | 38.43 | 45.95 | 1.54 | 3.16 | 9.86 | 14.52 | .... |
| D. W..... | 0 | .12 | .03 | .97 | 6.33 | 37.90 | 6.91 | 4.42 | 43.40 | 54.73 | .... |
| Diameter | | | | | | | | | | | |
| T. W..... | .. | .566 | .178 | .1144 | 0.0080 | 0.0051 | 0.0026 | 0.0024 | 0.0015 | 0.0022 | .... |
| D. W..... | .. | .566 | 1.78 | .1144 | .0348 | .0099 | .0064 | .0038 | .0024 | .0042 | .... |
| Sur. Fact. | | | | | | | | | | | |
| T. W..... | .. | .21 | .17 | 8.49 | 4804.0 | 9010.0 | 591.3 | 1317.0 | 6547.0 | 8455.3 | 22278.17 |
| D. W..... | .. | .21 | .17 | .49 | 181.0 | 2818.0 | 1080.0 | 1163.0 | 18080.0 | 20323.0 | 23331.81 |
| 1.33 | | | | | | | | | | | |
| Claymont, Ga. | | | | | | | | | | | |
| Per cent | | | | | | | | | | | |
| T. W..... | 0 | 0 | 0 | 0.7 | 0.15 | 14.00 | 16.23 | 39.73 | 29.20 | 85.16 | .... |
| D. W..... | 0 | 0 | 0 | .7 | 6.83 | 2.20 | 10.68 | 22.60 | 57.00 | 90.28 | .... |
| Diameter | | | | | | | | | | | |
| T. W..... | .. | .. | .. | .1144 | 0.0121 | 0.0092 | 0.0052 | 0.0031 | 0.0020 | 0.0034 | .... |
| D. W..... | .. | .. | .. | .1144 | .0267 | .0175 | .0098 | .0037 | .0023 | .0053 | .... |
| Sur. Fact. | | | | | | | | | | | |
| T. W..... | .. | .. | .. | 6.12 | 12.40 | 1522.0 | 3115.0 | 12610.0 | 14600.0 | 30325.0 | 31865.5 |
| D. W..... | .. | .. | .. | .12 | 6.11 | 125.7 | 1090.0 | 6108.0 | 24780.0 | 31978.0 | 32115.9 |

17.0
Columbia, S. C.

Per cent

| | | | | | | | | | | | |
|-----------|---|---|---|-----|-------|-------|-------|------|-------|-------|------|
| T. W..... | 0 | 0 | 0 | 0.2 | 10.90 | 44.30 | 28.60 | 1.25 | 14.60 | 44.45 | .... |
| D. W..... | 0 | 0 | 0 | .2 | .72 | 21.30 | 47.50 | 3.11 | 17.25 | 67.86 | .... |

Diameter

| | | | | | | | | | | | |
|-----------|-----|-----|-----|-------|--------|--------|--------|--------|--------|--------|------|
| T. W..... | ... | ... | ... | .1144 | 0.0099 | 0.0048 | 0.0045 | 0.0030 | 0.0018 | 0.0031 | .... |
| D. W..... | ... | ... | ... | .1144 | .0069 | .0059 | .0028 | .0025 | .0016 | .0023 | .... |

Sur. Fact.

| | | | | | | | | | | | |
|-----------|-----|-----|-----|------|--------|--------|---------|--------|---------|---------|---------|
| T. W..... | ... | ... | ... | 1.75 | 1101.0 | 9229.0 | 6356.0 | 416.7 | 811.0 | 14883.7 | 25215.5 |
| D. W..... | ... | ... | ... | .75 | 1518.0 | 3610.0 | 16960.0 | 1080.0 | 10780.0 | 37820.0 | 33949.7 |

1.17

Langley, S. C.

Per cent

| | | | | | | | | | | | |
|-----------|-----|-----|-----|------|------|------|------|------|-------|-------|------|
| T. W..... | 0 | 0 | 0 | 0 | 0 | 17.0 | 72.0 | 5.9 | 5.1 | 82.0 | .... |
| D. W..... | ... | ... | ... | .... | .... | 0 | 1.68 | 5.61 | 92.72 | 100.0 | .... |

Diameter

| | | | | | | | | | | | |
|-----------|-----|-----|-----|------|------|--------|--------|--------|--------|--------|------|
| T. W..... | ... | ... | ... | .... | .... | 0.0048 | 0.0029 | 0.0019 | 0.0012 | 0.0020 | .... |
| D. W..... | ... | ... | ... | .... | .... | .... | .0041 | .0032 | .0026 | .0036 | .... |

Sur. Fact.

| | | | | | | | | | | | |
|-----------|-----|-----|-----|------|------|-------|---------|--------|---------|---------|---------|
| T. W..... | ... | ... | ... | .... | .... | .3542 | 23170.0 | 1121.0 | 4250.0 | 28541.0 | 37083.0 |
| D. W..... | ... | ... | ... | .... | .... | .... | 406.8 | 1781.0 | 35660.0 | 37847.8 | 37847.8 |

The Jackson-Purdy surface factor was used to express the fineness of grain which is inversely proportional to the diameter of the particles. For example:

| | Per cent | Diam. | | Surface factor |
|------------------------------------|----------|-------|-------------------------|----------------|
| > 20 mesh = | 38.60 | 2.00 | $38.60 \frac{1}{2}$ | = 19.30 |
| 20-65 mesh = | 7.08 | 0.566 | $7.08 \frac{1}{0.566}$ | = 12.51 |
| 65-100 mesh = | 0.65 | .178 | $0.65 \frac{1}{.178}$ | = 3.61 |
| 100-200 mesh = | 5.80 | .114 | $5.80 \frac{1}{.114}$ | = 30.88 |
| Can 1 = | 11.25 | .0315 | $11.25 \frac{1}{.0315}$ | = 349.00 |
| Can 2 = | 5.78 | .0210 | $5.78 \frac{1}{.0210}$ | = 375.00 |
| Can 3 = | 7.94 | .0112 | $7.94 \frac{1}{.0112}$ | = 708.90 |
| Can 4 = | 5.70 | .0070 | $5.70 \frac{1}{.0070}$ | = 812.40 |
| Overflow = | 17.15 | .0044 | $17.15 \frac{1}{.0044}$ | = 3,898.00 |
| Total surface factor of clay . . . | | | | 6,209.60 |

Results of Work

Tap Water Compared with Distilled Water in Elutriation Tests.—Figures 3-4 and table 1 show the results obtained by using tap and distilled water in the elutriation of the same clays. It is obvious that the per cent clay deposited in cans 1 and 2 is much greater when tap water is used than when distilled water is employed. This is due to the presence of soluble sulphates and bicarbonates in Columbus tap water which coagulate the finer clay particles, causing them to settle as larger particles. An analysis¹ of the Columbus tap water is as follows:

¹ Analysis was furnished by C. P. Hoover, Chemist of the Columbus Water Softening and Purification Works.

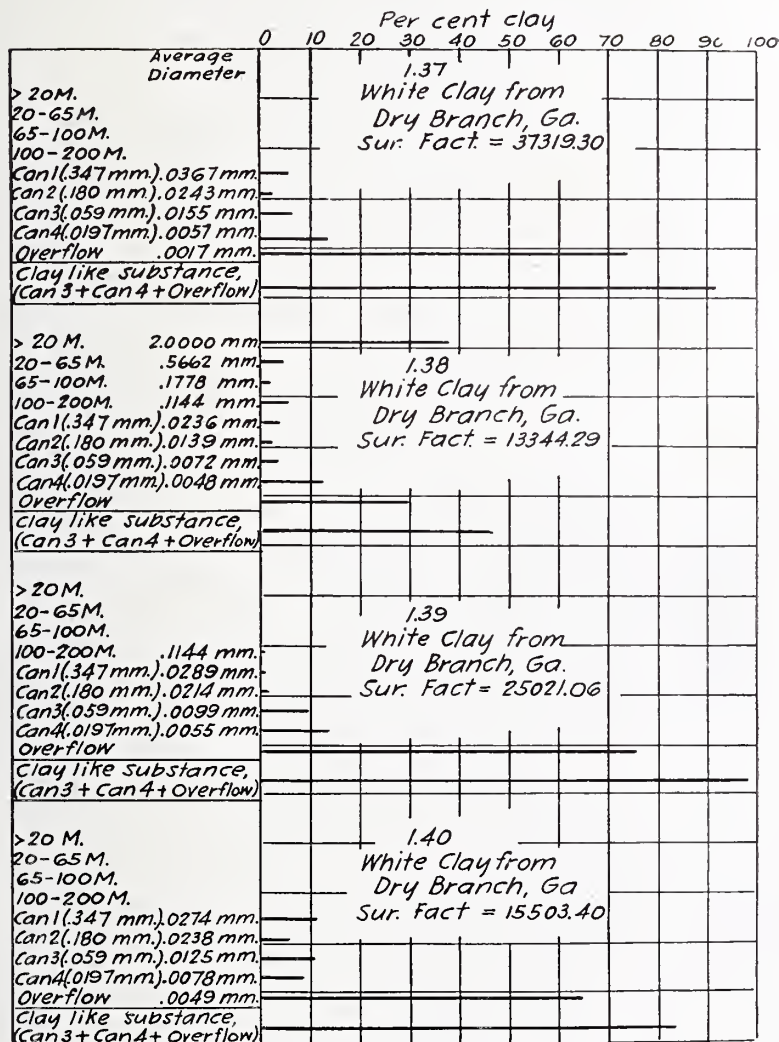


FIG. 5.—Elutriation tests on some Georgia white clays

| | Parts per million | Probable hypothetical combination | Parts per million |
|------------------------|-------------------|-----------------------------------|-------------------|
| Total solids..... | 220 | | |
| Ignition loss..... | 88 | | |
| Alkalinity..... | 43 | | |
| Bicarbonates..... | 35 | | |
| Normal carbonates..... | 8 | | |
| Incrustants | 47 | Calcium carbonate | 43 |
| Total hardness..... | 90 | Calcium sulfate | 7 |
| Calcium..... | 19 | Magnesium sulfate | 44 |
| Magnesium..... | 9 | Sodium chloride | 10 |
| SO ₄ | 6 | Sodium sulfate | 36 |
| Chlorine..... | 6 | | |
| Iron and aluminum..... | Trace | | |

The diameters of the particles in cans 1 and 2 separated with tap water are smaller than those of particles separated in the same

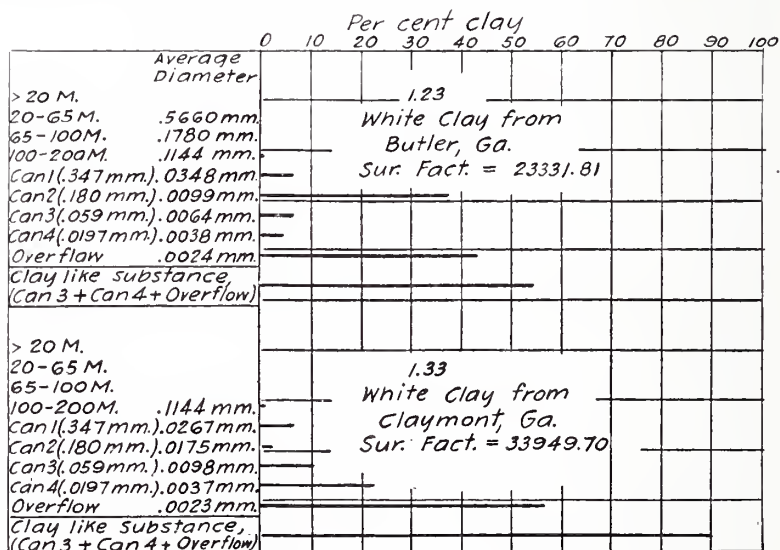


FIG. 6.—Elutriation tests on some Georgia white clays.

cans with distilled water. This may be due to the fact that a large number of fine particles form floccules which, when highly magnified, appear as a number of small grains instead of one large particle.

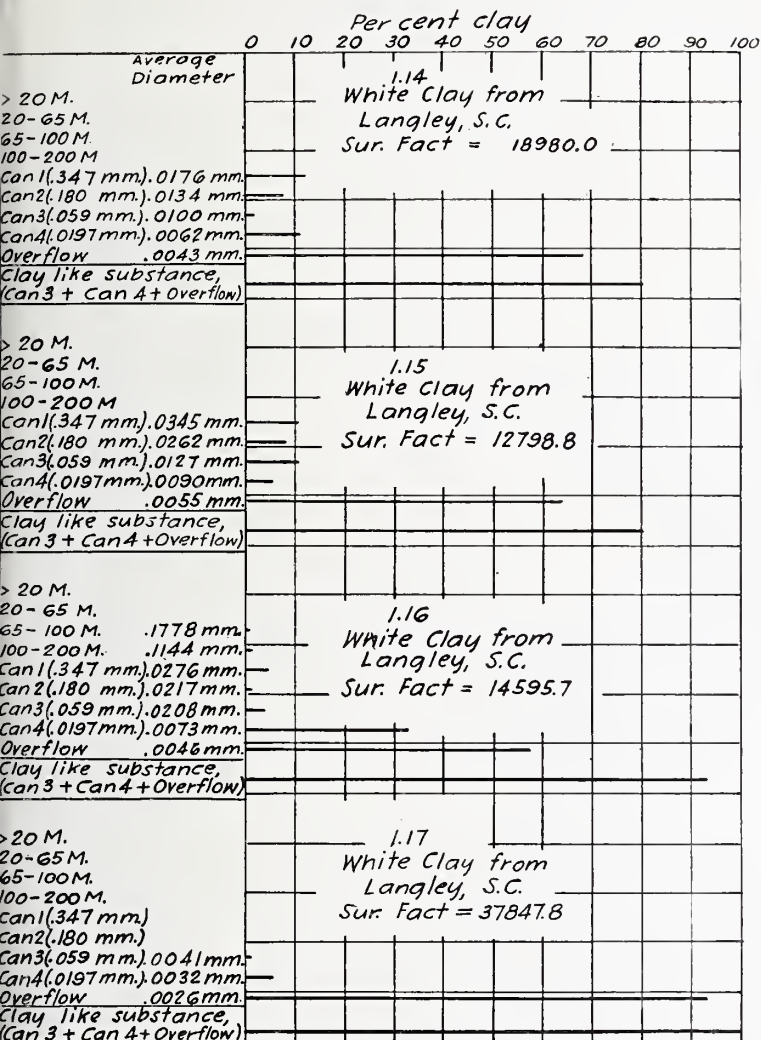


FIG. 7.—Elutriation tests on some South Carolina white clays.

The surface factor obtained when distilled water is used is somewhat larger than that obtained when tap water is used.

It was also found that the results checked much closer with distilled water than with tap water.

A Comparison of the Different Kaolins.—Table 2 and figures 5 and 6 contain the results of tests on Georgia kaolins. In general it might be said that with few exceptions the Georgia white clays

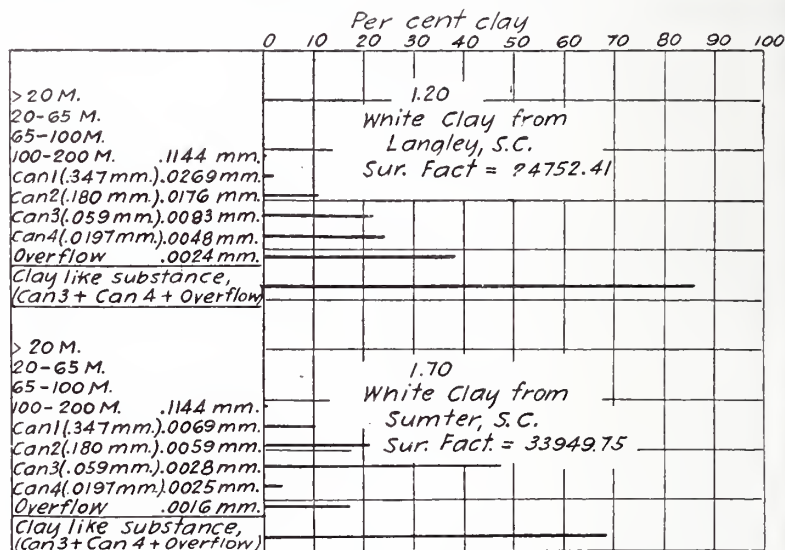


FIG. 8.—Elutriation tests on some South Carolina white clays.

show a comparatively high per cent of clay-like substance, *i. e.*, material smaller than 0.010 mm. in diameter.

Table 3 and figures 7 and 8 show the degree of fineness of South Carolina kaolins and these also appear to have a comparatively high per cent of clay substance smaller than 0.010 mm., comparing favorably with Georgia kaolin in this respect.

In table 4 and figures 9 and 10 are the results of the elutriation tests on other American kaolins. Both North Carolina clays tested show an abnormally low per cent of material below 0.010 mm. The Pennsylvania kaolins have a fairly high content of material below 0.010 mm. diameter.

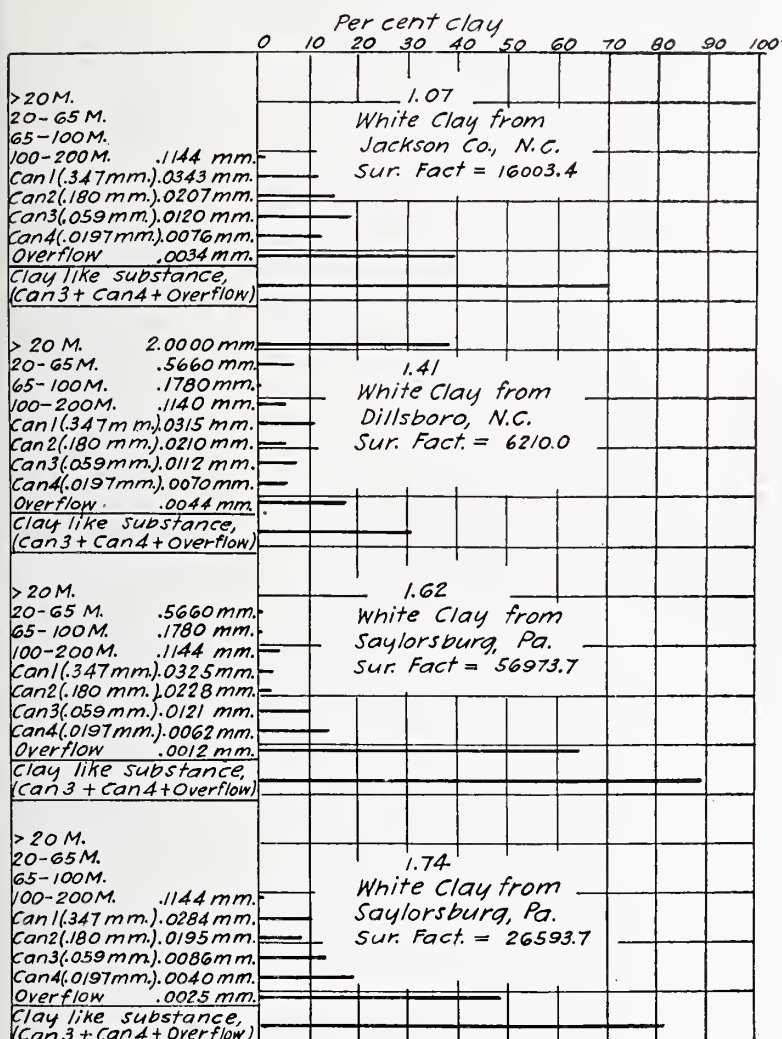


FIG. 9.—Elutriation tests on miscellaneous white clays.

TABLE 4—ELUTRIATION TESTS ON MISCELLANEOUS KAOLINS USING DISTILLED WATER

| Sample | 20 M. | 20-65 M. | 100-200 M. | Can 1 Veloc. 0.347 mm. | Can 2 Veloc. 0.180 mm. | Can 3 Veloc. 0.059 mm. | Can 4 Veloc. 0.0197 mm. | Overflow | Can 3+ Can 4+ Overflow | Total surface factor |
|---------------------------|-------|----------|------------|------------------------|------------------------|------------------------|-------------------------|----------|------------------------|----------------------|
| 1.07 | | | | | | | | | | |
| Jackson Co., N. C. | | | | | | | | | | |
| Per cent.... | 0 | 0 | 1.75 | 12.00 | 15.29 | 18.93 | 12.25 | 39.80 | 70.98 | .... |
| Diameter... | ... | .... | 0.1144 | 0.0343 | 0.0207 | 0.0120 | 0.0076 | 0.0034 | 0.0073 | .... |
| Sur. Fact... | ... | .... | 15.30 | 349.50 | 738.60 | 1577.00 | 1612.00 | 11710.00 | 14900.00 | 16003.4 |
| 1.41 | | | | | | | | | | |
| Dillsboro, N. C. | | | | | | | | | | |
| Per cent.. | 38.60 | 7.08 | 0.65 | 11.85 | 5.78 | 7.94 | 5.70 | 17.15 | 30.79 | .... |
| Diameter.. | 2.00 | 0.566 | .178 | 0.0315 | 0.0210 | 0.0112 | 0.0070 | 0.0044 | 0.0075 | .... |
| Sur. Fact.. | 19.30 | 12.51 | 3.61 | 349.00 | 375.20 | 708.90 | 812.40 | 3898.0 | 5419.30 | 6210.00 |
| 1.62 | | | | | | | | | | |
| Saylorsburg, Pa. | | | | | | | | | | |
| Per cent... | 0 | 0.9 | 0.66 | 2.62 | 2.94 | 10.50 | 14.13 | 64.40 | 89.03 | .... |
| Diameter.. | ... | .566 | .178 | 0.0325 | 0.0228 | 0.0121 | 0.0062 | 0.0012 | 0.0033 | .... |
| Sur. Fact.. | ... | 1.59 | 3.71 | 80.61 | 129.00 | 867.90 | 2227.00 | 53670.00 | 56764.90 | 56973.7 |
| 1.74 | | | | | | | | | | |
| Saylorsburg, Pa. | | | | | | | | | | |
| Per cent... | 0 | 0 | 0.38 | 10.06 | 8.03 | 13.45 | 19.58 | 48.50 | 81.53 | .... |
| Diameter.. | ... | .... | .1144 | 0.0284 | 0.0195 | 0.0086 | 0.0040 | 0.0025 | 0.0050 | .... |
| Sur. Fact.. | ... | .... | 3.321 | 354.2 | 413.2 | 1528.0 | 4895.0 | 19400.0 | 25823.0 | 26593.7 |
| 1.58-9 | | | | | | | | | | |
| Hockessin, Del. | | | | | | | | | | |
| Per cent... | 14.50 | 14.40 | 2.12 | 3.91 | 10.88 | 10.95 | 16.90 | 20.70 | 48.55 | .... |
| Diameter.. | 2.00 | 0.566 | 0.178 | 0.1144 | 0.0280 | 0.0187 | 0.0111 | 0.0077 | 0.0080 | .... |

Table 5 and figure 10 show the results obtained with English china and ball clays. English china clay shows a comparatively high per cent of material smaller than 0.010 mm.; 40.75 per cent was carried away by the overflow. English ball clay contains an extremely high per cent of fine material, 98.55 per

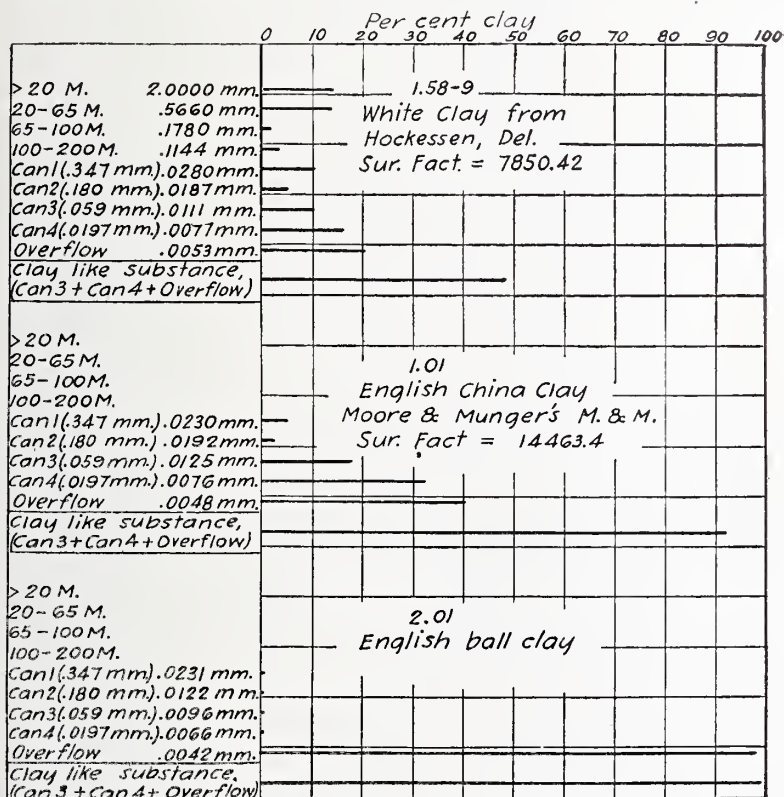


FIG. 10.—Elutriation tests on miscellaneous white clays.

cent being carried away by the overflow. It, therefore, appears that the greater plasticity and bonding strength of ball clays, as compared to kaolins, may be due to their finer grains.

Comparison of Calculated and Observed Results.—Below are given results obtained with varying velocities using both tap and

distilled water; also those obtained by calculation, using Schöne's empirical formula.

| | No. of clays tested | Velocities of flow in mm. per second | | | |
|---|---------------------------|--------------------------------------|--------|--------|--------|
| | | 0.347 | 0.180 | 0.059 | 0.0197 |
| Calculated diameters..... | .. | 0.0160 | 0.0105 | 0.0052 | 0.0026 |
| Diameters obtained with dis- tilled water..... | 14 | .0177 | .0098 | .0055 | .0033 |
| Diameters obtained with tap water..... | 4 | .0060 | .0038 | .0027 | .0018 |

The above table shows that the average diameters obtained with distilled water are fairly close to the calculated diameters. Schöne's formula applies to spherical particles, and the slight difference between the observed diameters and the calculated may be due to the irregular shapes of the clay particles. When using tap water the diameters are much smaller than the calculated diameters.

Summary

The elutriation of kaolins should be carried on with distilled water instead of tap water as the soluble salts in tap water cause the clay particles to coagulate and settle as larger grains.

The residue in each can should be thoroughly stirred each day to overcome the error due to settling of fine particles on the sides of the cone. This may be done by stopping the water flow and gently blowing air through the stem of the thistle tubes. Each sample should be elutriated for at least three days to insure a complete separation, or until the overflow from the last can is clear.

Results check more closely when the residues are stirred at intervals and when distilled water is used in place of tap water.

The clays should be deflocculated and fed into the elutriator, drop by drop, and during this period the velocity of the flow should remain about one-third below maximum.

It was found that the Georgia, South Carolina and Pennsylvania kaolins tested in this investigation contain a high per cent of clay-like substance below 0.010 mm., comparing favorably with the English china clay in this respect.

The North Carolina kaolins tested showed a comparatively low per cent of fine or clay-like substance.

English ball clay contains an extremely high per cent of fine material, 98.55 per cent being carried away by a flow of 0.0197 mm. per second. Only 40.75 per cent of English kaolin was carried off by this velocity. It is evident that the greater plasticity and bonding strength of ball clays, as compared to kaolins, is due largely to their finer grains.

The observed diameters of the particles, as separated with distilled water, correspond reasonably close to the calculated results obtained by using Schöne's empirical formula.

In conclusion, the author wishes to acknowledge his indebtedness to Mr. R. T. Stull and M. C. Booze for the design and construction of the apparatus.

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MINING EXPERIMENT STATION, COLUMBUS, OHIO

NOTICE.—Further discussion of this general subject is solicited. All communications should be sent to the Editor.

THE CHOICE OF GLASS BATCHES CONTAINING LIME¹

By W. E. S. TURNER

Through the kindness of Dr. Tillotson, the writer has just received a copy of the very interesting and useful report by Dr. Fettke entitled "Glass Manufacture and the Glass Sand Industry of Pennsylvania." In it there is a reference which has suggested this communication in regard to the choice of glass batches, the chief constituents of which are silica (sand), lime and alkali.

On pages 90-95 are quoted a number of batches for various purposes, including table ware, plate glass, lime, flint, and bottle glasses. For the production of the last-named type, the following are quoted:

| | American (3) | American (4) | American (4) | American (4) | American (4) |
|----------------|------------------|-----------------|-----------------|-----------------|-----------------|
| Sand..... | 100 | 100 | 100 | 100 | 100 |
| Limestone..... | 30 | 36 | 32 | 34 | 36 |
| Soda ash..... | 27 $\frac{1}{2}$ | 38 | 35 | ... | ... |
| Salt cake..... | ... | ... | ... | 38 | 42 |
| Salt..... | 3 $\frac{1}{8}$ | ... | ... | ... | ... |
| Carbon..... | ... | ... | ... | 5 | 8 |

It is not easy, unless one is fairly closely in touch with the industry, to know what batches are in common use, and the author of this excellent report was obliged to have recourse for them to early publications as far back as 1883² and 1899.³

The writer is of the opinion, however, that bottle batches of the type quoted have almost, if not entirely, disappeared from American factories, certainly from those employing automatic or semi-automatic machines. The batches with high lime content are still to be found in use in Europe, since they are eminently

¹ Received Feb. 27, 1920.

² Report on the manufacture of glass, by Jos. D. Weeks, 1883, Census Report.

³ Glass, Robert Linton, "The Mineral Industry for 1889," Vol. 9, pp. 234-263.

suitable for hand-working and are used also in certain types of semi-automatic machines (such as the Horne, the Simpson and the Johnny Bull), which are less highly productive than the modern types. The introduction of machines like the Owens, the Hartford-Fairmont, O'Neill, Millar, Lynch and other types, whether hand fed (in the last three cases), or automatically fed, has not only revolutionized production but has changed markedly the composition of the batch, leading to the introduction of a type similar to that described by Fette under the term "lime-flint," namely, one similar to the following:

| | American (3) |
|----------------------|------------------|
| Sand..... | 100 |
| Lime..... | 10 |
| Soda ash..... | 33 $\frac{1}{3}$ |
| Chili saltpeter..... | 13 $\frac{1}{3}$ |

The choice of a glass batch, and in particular of the lime-soda batches, is affected very largely by the mode of working the glass. A glass with a high lime content sets quickly and is, for this reason, suitable for hand-working as the blower does not have to wait unnecessarily after gathering and marvering the metal. Glasses even with higher lime content than numbers 12 and 13 (p. 382) have been used for hand-blowing. Where, however, the glass comes into contact with a mass of iron work which would chill it fairly rapidly, as in machines where the bottle passes through several stations on each of two tables, or on two tiers around a central body, the use of a high lime glass would be either impossible or be attended with difficulty. Moreover, if the machine be fed by an automatic flowing or feed-device, the orifice of the flow would probably tend to become choked as the result of devitrification, a phenomenon which the moderately high lime glasses often exhibit.

For the sake of the mechanical devices, therefore, bottle batches are now much softer, a condition obtained by reducing the lime content very considerably and raising, correspondingly, the alkali content. There are quite a number of advantages. In the first place the high soda, low lime glass melts much more readily than the older batches for hand operation, and production of glass can be speeded up in consequence. Next the glass is softer, and the

bottle can be readily blown up or pressed to its normal shape, whereas when a high lime batch has been used, trouble has frequently been found, especially with narrow-mouth ware, in that the neck near the mouth has not been fully blown up owing to setting too quickly; several bottles and jars can be collected before conveying them to the lehr, whereas the high lime glass must be transferred to the annealing oven much more quickly. For the same reason, the high lime glass could not be so successfully transferred to the lehr by an automatic conveyor because of its rapid setting. Fourthly, the "limeflint" glass requires a distinctly lower annealing temperature than the high lime glass¹ and can therefore be annealed more quickly. A high lime glass has the virtue of smaller expansion for heat than the lime flint glass, but on the other hand has a higher conductivity for heat which causes it to cool rapidly, so that if its temperature falls distinctly below the required annealing temperatures before it is placed in the lehr, strains may be set up which result in cracking. The disadvantage attending the higher coefficient of expansion of the high soda glass is readily avoided by preventing entrance of draught in the lehr.

This account does not quite complete the comparison of the relative merits of the high lime and the lime flint glasses, but it will at any rate serve to indicate the reason why the latter have come into general employment in the bottle industry.

But while the lime flint glass has so many advantages for machine use, it must be borne in mind that the resistance which glass shows toward the atmosphere and to liquids it contains is reduced stage by stage as the amount of alkali is increased. Lime in a well-annealed glass makes very strongly for durability.

The question therefore arises as to how far the softening process can, with safety, proceed, and this question is of importance, not only for bottle glass, but for all other types of lime-soda glass. In order to answer this question, a series of glasses, numbers 1 to 13 (p. 382), were prepared on a semi-commercial scale in the writer's department and were subjected to treatment by boiling water and boiling solutions of strong caustic alkali, sodium carbonate

¹ See English, S. and Turner, W. E. S., *J. Soc. Glass Tech. Trans.*, 3, 125 (1919).

and hydrochloric acid, for six hours with water and hydrochloric acid, three hours with caustic soda (2N.-NaOH) and sodium carbonate (2N.-Na₂CO₃).

The batch composition of the glass as shown in table 1, numbers 12 and 13, as already stated, being typical bottle batches for hand-working.

TABLE 1

| No. of glass | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|--------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|------|------|
| Sand | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Soda ash | 590 | 560 | 530 | 501 | 471 | 441 | 412 | 383 | 353 | 324 | 295 | 365 | 285 |
| Limespar | .... | 28 | 55 | 83 | 111 | 139 | 166 | 194 | 222 | 250 | 278 | 500 | 450 |
| Arsenic | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 7 | 7 |

Since ordinary commercial materials were employed in the preparation it is desirable to state the actual compositions of the finished glasses. These are shown in table 2.

TABLE 2—COMPOSITION OF THE LIME-SODA SERIES OF GLASSES

| Glass | SiO ₂ | Na ₂ O | CaO | MgO | Al ₂ O ₃ | Fe ₂ O ₃ | As ₂ O ₃ | Total |
|---------|------------------|-------------------|-------|-------|--------------------------------|--------------------------------|--------------------------------|--------|
| 1..... | 74.05 | 25.34 | 0.21 | Trace | 0.24 | 0.14 | .. | 99.98 |
| 2..... | 73.92 | 23.80 | 1.50 | Trace | .20 | .14 | .. | 99.56 |
| 3..... | 74.08 | 23.00 | 2.61 | Trace | .21 | .15 | .. | 100.05 |
| 4..... | 74.07 | 21.50 | 3.81 | Trace | .28 | .15 | .. | 99.80 |
| 5..... | 73.78 | 20.78 | 4.50 | 0.15 | .38 | .19 | .. | 99.78 |
| 6..... | 73.18 | 19.38 | 6.26 | .21 | .58 | .61 | .. | 100.22 |
| 7..... | 74.41 | 17.20 | 7.45 | .24 | .30 | .40 | .. | 100.00 |
| 8..... | 74.99 | 16.00 | 8.16 | .26 | .31 | .09 | .. | 99.81 |
| 9..... | 74.96 | 14.88 | 9.36 | .28 | .42 | .16 | .. | 100.08 |
| 10..... | 74.59 | 14.22 | 10.38 | .30 | .45 | .21 | .. | 100.15 |
| 11..... | 74.93 | 13.02 | 11.68 | .31 | .38 | .17 | .. | 100.49 |
| 12..... | 66.71 | 12.72 | 18.17 | .85 | 1.41 | .31 | 0.30 | 100.47 |
| 13..... | 69.73 | 11.22 | 17.38 | .55 | 0.50 | .25 | .47 | 100.10 |

The results of the tests are recorded in table 3, in which the effect of the several reagents is measured by the loss in weight suffered by each 100 square centimeters of the surface.

It will be noted that water is the most corrosive liquid when either no lime or very little lime is present, while strange as it may seem, the strong caustic alkali has least effect.

It will be noted, further, that as the amount of lime is increased the corrosive action very rapidly falls off. At glass 6, we reach the border line of what may, for ordinary commercial purposes

TABLE 3—SUMMARY OF RESULTS

(Expressed in mg. per 100 sq. cm.)

| Glass | Boiling water Loss in wt. | 2N.NaOH Loss in wt. | 2N.Na ₂ CO ₃ Loss in wt. | 20.24% HCl Loss in wt. |
|---------|------------------------------|------------------------|---|---------------------------|
| 1..... | 24000.0 | 65.2 | 4618.5 | 158.4 |
| 2..... | 335.4 | 61.1 | 234.0 | 71.4 |
| 3..... | 157.9 | 60.6 | 83.8 | 18.0 |
| 4..... | 20.9 | 58.8 | 45.5 | 10.2 |
| 5..... | 10.5 | 56.0 | 35.5 | 6.2 |
| 6..... | 2.5 | 53.6 | 32.3 | 4.6 |
| 7..... | 1.9 | 51.2 | 30.3 | 3.5 |
| 8..... | 1.4 | 49.4 | 27.8 | 2.5 |
| 9..... | 0.62 | 46.9 | 26.7 | 1.5 |
| 10..... | .57 | 44.6 | 26.0 | 1.0 |
| 11..... | .53 | 42.1 | 25.1 | 0.85 |
| 12..... | .70 | 46.3 | 32.7 | 1.7 |
| 13..... | .60 | 49.8 | 25.0 | 1.1 |

be used with safety. Glass 6 is not quite satisfactory, however. When powdered finely it was found to attract moisture slowly but quite appreciably so that even in article form the same trouble will eventually be discovered.

For general machine use, as well as for hand lime flint operations, glasses 7 to 9 are most satisfactory, 7 containing the lowest limit of lime which is consistent with safety in the above batches. Glasses of this type are commonly in use for Owens machines and for semi-automatic machine with or without automatic feeding devices. On various occasions, however, the writer has found glasses in use made from batches below the lime content of glass 7. Such batches should be avoided.

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NOTICE.—Further discussion of this general subject is solicited. All communications should be sent to the Editor.

THE EFFECT OF VARIATION OF THE SIZE OF THE GROG IN TERRA COTTA BODIES¹

BY R. L. CLARE AND D. F. ALBERY

Introductory.—This investigation was prompted by the wide variation which occurs in the physical or screen analysis of the ground grog used in terra cotta bodies. We wished to know what effect, if any, this variation had on the physical properties of the body both in the unburned and in the burned conditions.

This grog is purchased in carload lots from jobbers, and little or no control can be exercised over the quality of the material received, either as to composition or hardness. It is simply a carload of saggars or fire brick picked up wherever the jobber finds them and sent to us in open cars for use in a mixture that should be accurately controlled in all its properties.

This material, if hard and dry when ground, will give a high proportion of coarse material and little or no dust, which is material finer than 100 mesh. If the material is soft and friable and wet when received, the resultant grog will show a very high percentage of dust. Both of these extremes occur frequently.

Experimental.—Our idea was to approximate in a mixture these extreme conditions met in factory practice. We therefore made up three bodies the same in all respects except for the variation in the physical analyses of the grog, as follows: One body marked "coarse" containing grog with a high percentage of coarse material; one body marked "medium" containing what we consider a well-balanced grog; one body marked "fine" containing grog with a high percentage of fine material. Each body was made up of two-thirds clay and one-third grog. The physical analyses of these grogs are given below.

We had pressed three pieces each of six different typical shapes from each of the three mixtures, representing the range of simple and difficult material in the factory. These were sprayed, one-half with glaze and one-half with vitreous slip, and burned as

¹ Received Feb. 27, 1920.

PHYSICAL ANALYSES OF GROGS

| | Coarse | Medium | Fine |
|-----------------------|--------|--------|-------|
| On 12 mesh..... | 0.2 | 0.1 | 0.0 |
| On 14 mesh..... | 33.0 | 11.4 | .1 |
| On 16 mesh..... | 4.5 | 2.9 | .1 |
| On 20 mesh..... | 7.8 | 5.3 | 1.3 |
| On 40 mesh..... | 33.5 | 34.3 | 28.9 |
| On 60 mesh..... | 6.1 | 13.4 | 20.3 |
| On 80 mesh..... | 2.6 | 5.7 | 8.6 |
| On 100 mesh..... | 2.0 | 4.4 | 6.5 |
| Through 100 mesh..... | 10.3 | 22.5 | 34.2 |
| | 100.0 | 100.0 | 100.0 |

follows: Two pieces of each shape to cone 6 in 110 hours and cooled in 150 hours, and one piece of each shape to cone 6 in 70 hours and cooled in 80 hours. All the pieces were then exposed

TABLE I

Pressing behavior:

| | |
|----------------|--|
| Coarse mixture | Rather unpleasant to handle, hard to roll, too sticky. |
| Medium mixture | Easy to press. |
| Fine mixture | Easy to press. |

Finishing behavior:

| | |
|----------------|--|
| Coarse mixture | Very hard to finish to a smooth surface, because of excess of coarse grit. |
| Medium mixture | Fairly easy to finish. |
| Fine mixture | Very easy to finish. |

Drying:

| | |
|----------------|--|
| Coarse mixture | This mixture would not dry straight. It seems to "set" quickly and when dry the ashlar pieces would be high in the center and reveal pieces out from the sides. In other words, the mixture did not seem to have the strength to draw the sides or faces "in" when drying, or else from the coarseness of the mixture the drying proceeded too rapidly and the material "set" too quickly. |
| Medium mixture | Dried straight. |
| Fine mixture | Dried straight. |

Cracking:

The fine mixture was the only one showing any tendency to crack during drying.

Dry shrinkage:

| | |
|----------------|--------------|
| Coarse mixture | 4.1 per cent |
| Medium mixture | 4.7 |
| Fine mixture | 4.8 |

to the weather for six months to allow for the development of any defects such as fire cracks, crazing, and so forth.

Careful records were made of the pressing, finishing, drying and shrinkage of each piece, and after burning each piece was tested for sound, warping, cracking, absorption, shrinkage and covering of the glaze. The sound test was made because we found that the mixture with the coarse grit had a very "shakey" or "punky" sound, not indicative of good strength.

Table 1 gives all the data on the unburned pieces, and table 2 on the burned pieces. The results noted are all average readings taken from the eighteen pieces made from each of the bodies.

TABLE 2—RESULTS OF 110-HOUR BURN

| | Sound | Warping | Cracking | Ab- sorp- tion* Per cent | Fire shrink- age Per cent | Glaze cover- ing |
|------------------|--------------|-------------------------|--------------------------------|--------------------------------------|---------------------------------------|------------------------|
| Coarse body..... | Shakey | None | None | 14.2 | 1.3 | Poor |
| Medium body... | Very firm | Very slight | 33% pieces slight cracks | 13.2 | 2.5 | Good |
| Fine body..... | Tight | 33% pieces warped | 50% pieces slight cracks | 12.9 | 1.8 | Very good |

* Forty-eight hours' soaking.

Results of 70-Hour Burn.—The pieces from the seventy-hour burn gave practically the same results as shown above except as regards fire cracking or dunting. One of the largest shapes from the medium body and two from the fine body were badly fire-cracked, indicating that this treatment was too severe for pieces of that shape pressed from the bodies noted.

Summary.—In the unburned state the coarse mixture reduced the drying shrinkage, increased the difficulties in pressing and finishing and did not dry straight.

The medium mixture pressed well, finished fairly easily and dried straight without cracking.

The fine mixture pressed well, finished easily, increased the drying shrinkage, and showed a decided tendency to crack in drying.

In the burned state, the coarse mixture was distinctly weak as indicated by the sound test, showed no warping or cracking

comparatively low absorption, low fire shrinkage, and very poor glaze covering.

The medium mixture had good strength, very slight warping and cracking and good glaze covering.

The fine mixture was the strongest as indicated by the sound test, showed considerable warping and cracking, the lowest absorption and the best glaze covering.

The higher fire shrinkage of the medium body is probably explained by the fact that in a well-portioned grog, the fine particles fill the voids between the larger ones, allowing of a closer and more homogeneous body during firing.¹

The medium and fine bodies are stronger and tighter than the coarse body, undoubtedly because of the greater solution of the fine grit material during vitrification.

The fire cracked pieces in the medium and fine bodies, from the shorter burn, indicate that strains are more liable to occur in the tighter bodies and especially during rapid firing and cooling.

Conclusions.—The results show rather clearly that, if a terra cotta body is to be kept uniform as to its physical properties, the grog size must be controlled. It follows that to control the size you must also control the character and quality of the grog. This is hardly possible when buying grog in the open market as stated in the beginning. The only way this can be obtained is by having grog especially prepared for terra cotta purposes, and ground under stated conditions.

The most suitable material could be selected for the grog, it could be burned to the proper hardness and ground so as to give the best results in the body. This could be prepared at some central plant and each company assured of a steady supply of a uniform material, most suited for its needs. In this manner one source of serious trouble would be eliminated for all time, and a long step in advance taken for the terra cotta industry. The extra cost of the grog prepared in this manner, we believe, would be more than offset by the advantages obtained.

FEDERAL TERRA COTTA CO.
WOODBIDGE, N. J.

NOTICE.—Further discussion of this general subject is solicited. All communications should be sent to the Editor.

¹ Kirkpatrick, F. A., "Effect of Size of Grog in Fire Clay Bodies," *Trans. Amer. Ceram. Soc.*, Vol. 19, 268.

STUDIES IN PUG MILL CONTROL

By H. SPURRIER

The exacting demands made on certain electrical porcelains at the present time call for wonderful uniformity of body both as to the solid constituents and also as to voids due to air or firing vesicles. Granted a body of suitable composition as a whole, it becomes necessary that in order to realize the full benefit of such composition, it is imperative to ensure as complete homogeneity as possible. Unfortunately, ceramic bodies as at present constituted render an ideal or perfect inter-mixture of components entirely impossible with our present modes of preparation of such bodies.

The very common classification of body components into plastics and non-plastics also suggests another classification not so common, to be sure, but nevertheless quite as obvious. If one observes the passage of broken coal, or other similar material, down a chute, it at once becomes evident that the coarser parts are to be found principally congregated in the mid-stream. This suggests that the larger and more angular pieces, on account of their retardation of the general movement caused by the contact of their many points with the walls of the chute, are forced away from the chute wall and toward the center.

The feldspar and flint are the principal producers of friction in a porcelain mix whereas the clay may be looked upon as a lubricant, and in this sense we may classify ingredients of the mix into lubricants and non-lubricants. It is to be remembered that the kaolinite particles are usually exceedingly fine, so fine, indeed, that they largely fall into the ultra-microscopic category.

Now with this conception in mind, if the physical operation of a pug mill be considered, while pugging a small blank, say, of one inch diameter with a bore pin of one-eighth inch diameter, some light may be thrown upon the operation.

The walls of the pug mill and the central bar carrying the bore

pin will be the friction surfaces; and it is here that one would expect to find a disproportionate accumulation of lubricant or clay, resulting in the forcing of the non-plastics, spar and flint, and so forth, into the annulus between the exterior surface in contact with the mill wall, and the interior surface in contact with the pin bar and pin.

Segregation as outlined above, if at all aggravated, would necessarily result in the confusing phenomenon of cracking, warping and internal strain, coupled with physical weakness. For a long time just such segregation has been known to take place and was rendered evident by the examination of microsections taken entirely across the blank. On examinations with about 80 diameters of such a section, one can clearly see the accumulation of clay particles in greater proportion at the outside surface, which was slicked along the pug barrel, and the inside surface, which was slicked along the pin bar and pin.

This phenomenon is influenced by the pressure at which a mill works; and in an effort to determine the relation of working pressure to this segregation, recourse was had to a somewhat novel gauge used to determine the working pressure. In the accompanying sketch (figure 1) *a* is a meter length of barometer tube of 1 millimeter bore made fast to a larger glass tube, *C*, by means of a rubber stopper, *B*; a number eight stopper, *D*, is fitted over the free end of *C* so as to present the larger end to the aperture to be made in the pug mill. The tube *a* is closed at its free end *K*; at a point, *E*, is placed a short column of mercury; and at *F* is a short length of pipe cleaner which acts as a buffer.

The use of this simple and accurate device is obvious. When it is desired to take the working pressure of a pug mill, a hole is bored at the desired spot with a half-inch tap drill and tapped to receive a plug. The apparatus is held or fastened over the tapped hole in the pug so that the hole in *D* fairly covers it and the rubber stopper makes a tight joint. The point *E* of the mercury column being marked off on the glass tube with a wax pencil, the pug mill is started. The clay at once forces its way out of the mill and into the bore of *C*, which must be large enough to allow a column of clay to enter from the test hole without friction. The clay will continue to enter *C* until a pressure has been es-

tablished equal to the working pressure of the pug mill. The effect of this will be to push forward the column of mercury so compressing the air in front of it.

It will at once be seen that owing to the operation of Boyle's law, the mercury column will advance toward *K*, which position should be marked. The tube *a* may be graduated for convenience sake. If *E* advanced half way to *K*, it would have doubled the pressure in the tube, which means, of course, a pressure of 14.7 pounds per square inch above the atmosphere. In this way by

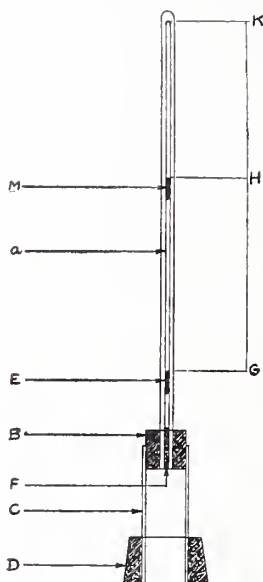


FIG. 1.

boring a number of holes, the working pressure of any part of the mill may be ascertained. Much useful information may also be arrived at concerning the working properties of different clays and clays of different degrees of stiffness.

By this little pressure device it has been shown that the pitch of pug mill blades was not correct, and that parts of the pug were not maintaining the proper pressure increase toward the die.

Another Form of Segregation

There is another form of segregation that vexes the soul of the clay worker, *viz.*, the uneven distribution of air. A single instance, taken from a special experimental pug mill installation, will illustrate this point.

A blank was bored from a diameter of five-sixteenth to one-half inch, and upon this portion a careful air determination made, which showed 11.9 per cent air by volume. The remainder of the blank, from one-half inch internal diameter to the outside, was then tested for air and showed 2.67 per cent by volume. Such differences as these are startling and at once led to a rigid investigation.

It became desirable to be able to determine differences in air content over very small areas, so small that a direct determination of air content became untrustworthy; consequently some other method had to be worked out that would give dependable results on areas separated by about one-sixteenth inch. Two new problems now presented themselves, the first being to produce such samples, the second being to determine the small differences looked for. Small differences in segregation, of the solid constituents, would not disturb the specific gravity a great deal, owing to the fact that the several constituents are so nearly alike in that property, kaolin being 2.5, flint 2.65, and anorthoclase 2.58.

A small difference in air content, however, would have a profound effect on the apparent specific gravity; accordingly the relative specific gravity of the several specimens was determined upon as being probably the most desirable property to investigate.

The Sampling Device

The specimens to be used were cylindrical, about one inch outside diameter, with a central bore of about 60/1000 inch diameter. On such a diameter it was desired to make about six comparisons of density. The blank was cut longitudinally into halves, a length of about one inch of the semi-circular bar was used. The section was placed in a little device carrying a saddle (2, figure 2). This in turn was mounted in a frame, 1, carrying midway and on either side an upright, 3, which in turn supported a swinging frame, 4, on the two pivots 5 which were easily withdrawn when

desired. The frame 4 was spanned by a number of cutting wires, 6, of 0.002 inch diameter. A stop, 7, served to arrest the movement of the swinging frame at the proper point. On swinging the frame

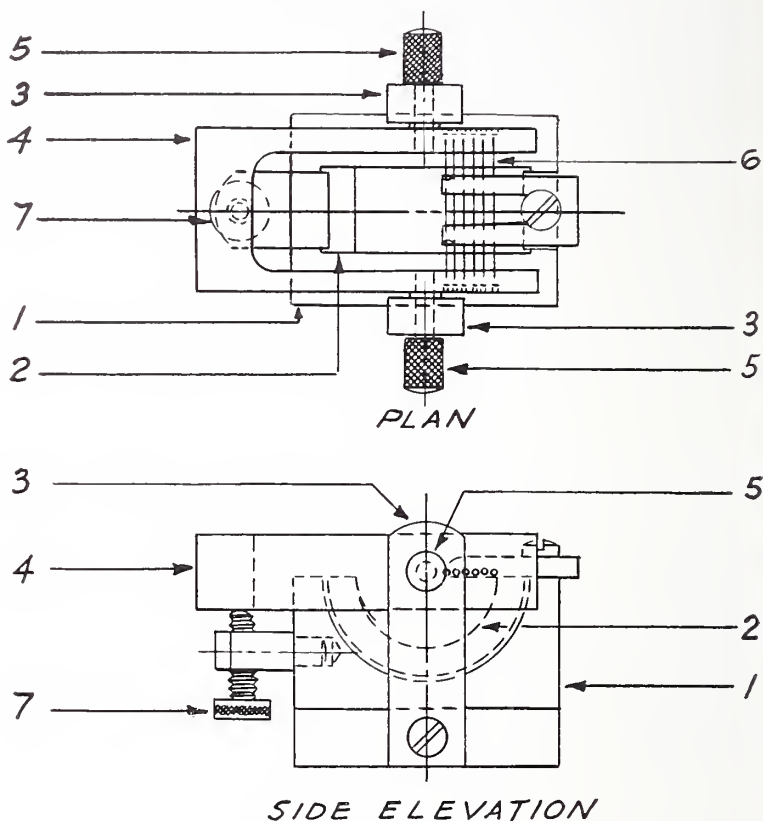


FIG. 2.—Apparatus for sampling clay blanks.

over from side to side the small blank will be cut into as many annuli as there are wires plus one.

Figure 3 shows the result of this operation. It will be seen that the piece may now be parted into leaves that serve for the test described. The attached figures are those used to denote the several sections and are those used as abscissas in the several graphs below. The sections were numbered by minute indentations made with a pointed wire.

Method of Differentiation

To differentiate between the several annuli, produced as above, recourse was had to gravity separation by dense solutions. The specific gravity of pugged clay bodies is usually in the neighborhood of 2; it was, therefore, possible to make a mixture of bromoform, specific gravity 2.8887, and carbon tetrachloride, specific gravity 1.5835, which would serve to float any section desired. Tetrachloride was added from a burette with suitable stirring, so managed as not to distort the specimens. As the solution gradually becomes lighter, a point is reached at which one section

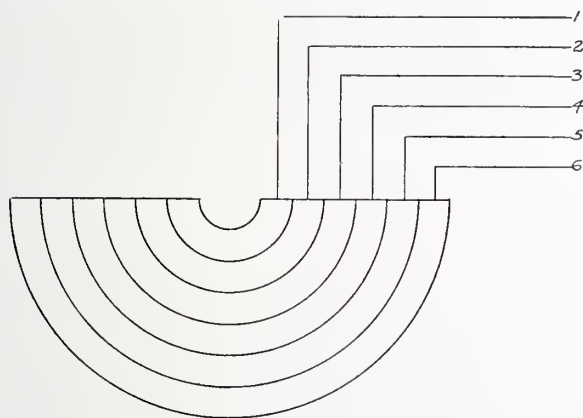


FIG. 3.

by its behavior indicates that it is about to sink; the tetrachloride is now added with considerable caution, care being taken to ensure thorough mixture after each addition.

When a section sinks, its number is recorded and so on until all but one have sunk. It is obviously unnecessary to cause the last section to sink; and moreover this would be objectionable as it is desirable to avoid undue dilution with the tetrachloride, which makes ultimate recovery of the two liquids more protracted.

The data obtained from such tests as above described have been plotted as graphs and when so portrayed and taken in conjunction with other data as to pug mill installation, speed of

pugging, water content, and so forth, bring to light many valuable facts not previously available.

In graph 1 as in all others the ordinates represent the order of sinking of the annuli as the liquid is gradually made less dense by very small decrements in specific gravity; the abscissas represent the various annuli as cut by the sampling device. The same order is maintained throughout.

In this case the center section sank first, meaning of course that it was specifically heaviest. The second section fell third. The third section fell fifth, the fourth sixth, the fifth fourth and the sixth second. The interpretation is that the body was densest in the center, grew regularly less dense until the third section was reached. The rate of decrease in density was reduced between the third and fourth section; from the fourth to the sixth section there was a regular increase in density, the sixth section being next in order of gravity to the first. In terms of air concentration this means that the air content is least at the outer and inner surfaces and increases toward the center, reaching a maximum at the fourth section.

In the second chart are two graphs, being a first and second run on a Crossley pug mill after changing the helix on the horizontal shaft. This illustrates the profound influence on the structure of the clay caused by an apparently insignificant change in the pug mill.

The difference in the two graphs may be due to a number of contributory causes, which is a subject for further experiment. However, it is certain that water content of the clay plays a profound part by its influence on the mobility of the mass. Another point is the great differences in the relation of stickiness to plasticity. Recent work in this laboratory has shown that it is possible to very definitely distinguish between these two properties, and it is hoped in the near future to be able to quantitatively determine and control the relation existing between them.

Chart 3 shows that the less dense area has been pushed a little toward the outside, and that the outer area 6 is rather denser than area 1, the center.

Chart 4 shows two runs with the same set-up, the first run is essentially similar to chart 3, excepting that the inner areas are a

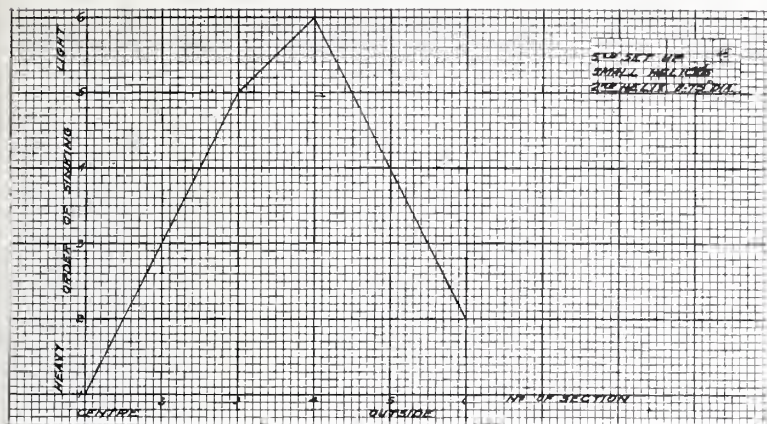


CHART 1.

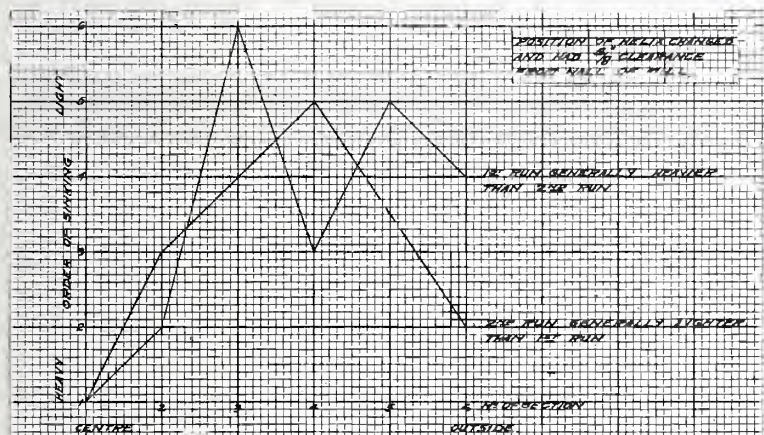


CHART 2.

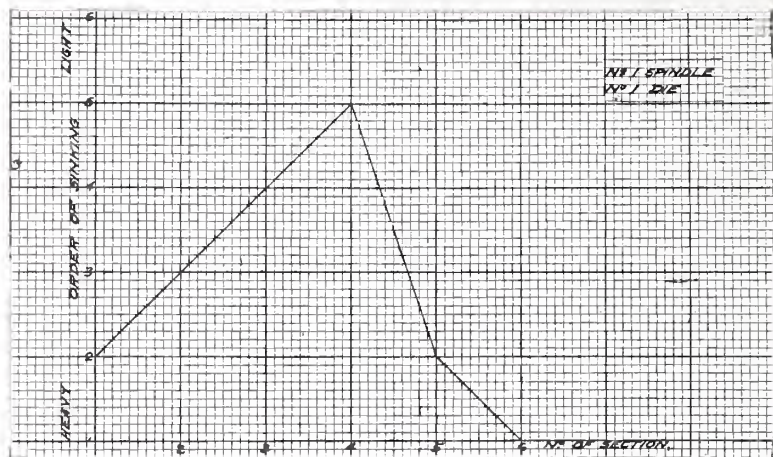


CHART 3.

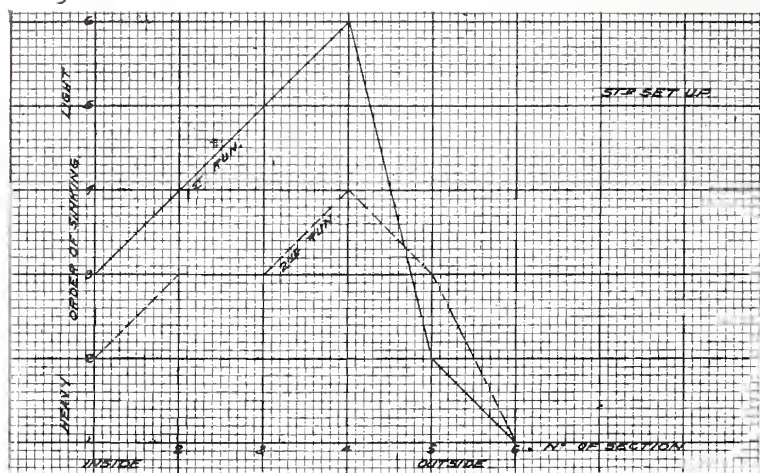


CHART 4

little lighter and the outer areas are a little denser relatively. The second run shows a slight decrease in density from the first to the second area, no change at all between second and third areas, the usual decrease at area four, and increased density from that outward.

Chart 5 is a specimen of clay, that, instead of being pugged, was hand-wedged and put through a die attached to a wad box.

Chart 6 shows two graphs of bodies of different composition, the density variations being essentially alike in the two bodies. These two bodies were hand-wedged and put through a wad box.

Charts 7 and 8 show the influence on the density distribution effected by changing the position of a small obstruction on the bore spindle.

Chart 9. These two charts represent a body of unusual homogeneity, especially is this so of run 2, there being no change in density between the second to the fifth area. The material represented by the second run is probably as good as will ever be obtained from a pug mill and certainly leaves very little to be desired on the score of homogeneity.

Specific Gravity Determinations on Small Samples

Interesting and unexpectedly good as the above results proved, it was still desirable to know something of the actual densities that these small sections showed and to be able to show in figures just what magnitude and relation existed.

Considerable care is necessary in taking small samples upon which accurate work must be done, in order to prevent drying during handling, as the loss of very little more water from one sample than from another might seriously affect the validity of the tests to be made. Therefore, all samples to be used on a given test should be prepared at the same time, and maintained under conditions that prevent change during handling.

In this work it was again necessary to devise sampling apparatus that would give the necessarily small sample of suitable shape and dimensions. Accordingly, the device illustrated in figure 4 was made. The round columnar blank was stood upright upon the piece 1, the brass top of which was slotted to receive the cutting wires shown in 3 and the piece 2 carrying the cutting grid 3

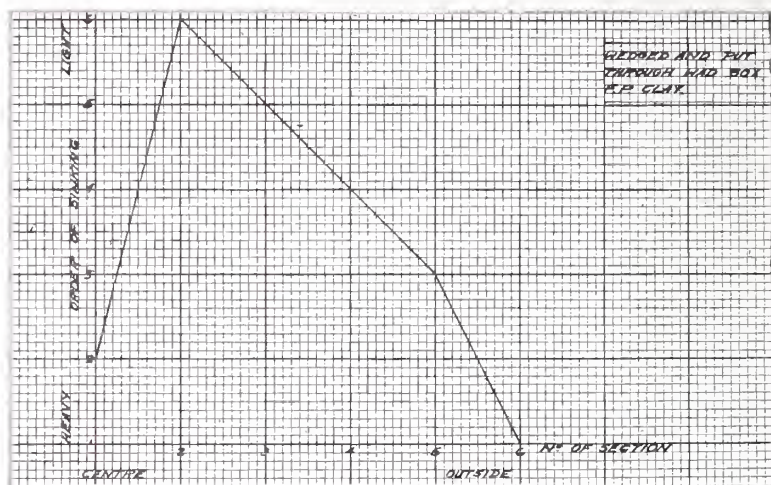


CHART 5.

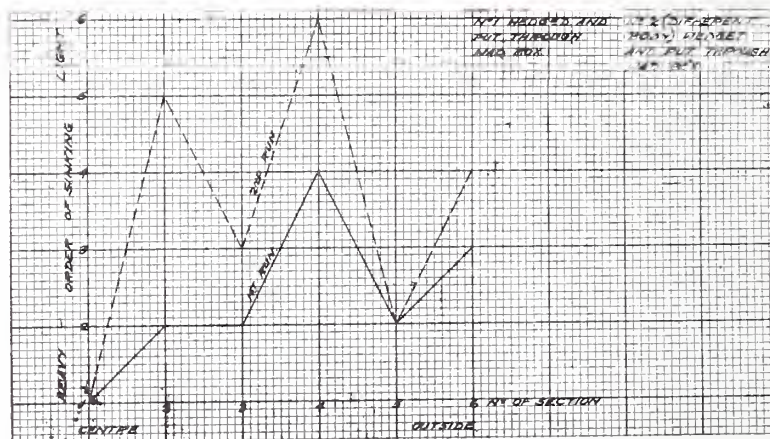


CHART 6.

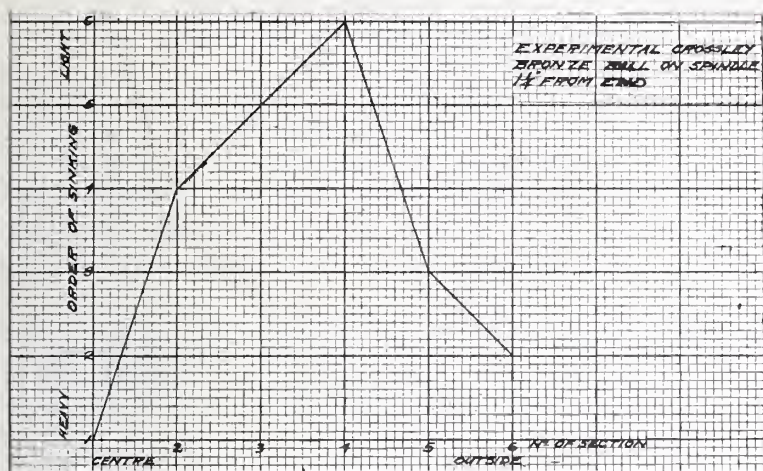


CHART 7.

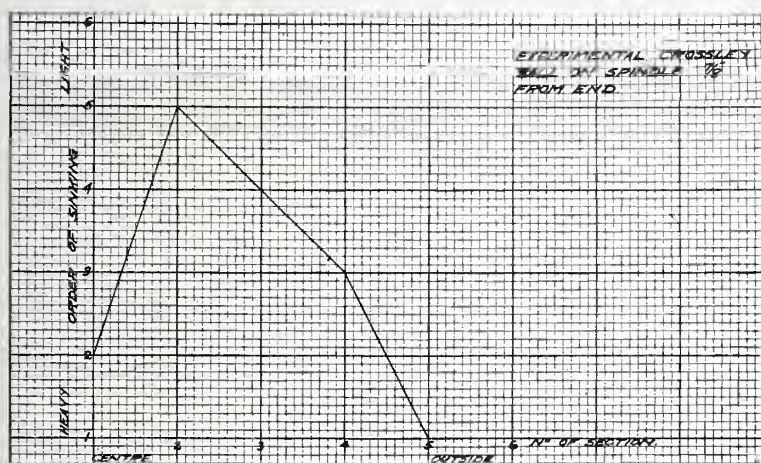


CHART 8.

composed of wires 0.002 inch diameter was slid over it and slowly pressed down until the clay blank was cut entirely lengthwise into square rods of suitable size.

A very delicate volumeter (figure 5) was then made as follows: A piece of glass tube, *A*, just large enough to allow the samples to be slid in without injury was bent into a "U." A length of small bore barometer tube, *B*, of even bore was selected and one end was heated, blown out and drawn down till the walls were of about the same thickness as those of the "U" previously made.

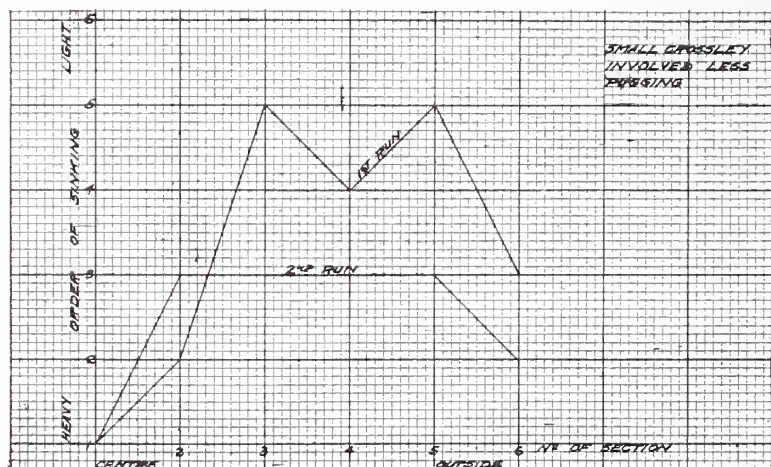


CHART 9.

This end was then cut off evenly and fused to one leg of the "U" at *C*. A line, *o*, was then struck on the upper part of the free end of the "U" and a corresponding mark was etched on the barometer glass tube. The longer tube was then carefully calibrated and graduated for a distance of 2 centimeters in terms of 0.01 centimeters; these fine graduations were sufficiently far apart to enable one to read to 0.0025 centimeter.

In order to use the instrument, it is mounted perfectly upright in a clamp, and filled to the zero mark on the wider tube with kerosene. Capillarity of course makes the kerosene rise above



the
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the zero on the barometer glass tube, which must be read off and used as a correction.

The specimen is carefully weighed in a specially made weighing tube and quickly slipped into the free end of the "U" tube, by inverting the weighing tube (of similar diameter) over it. There

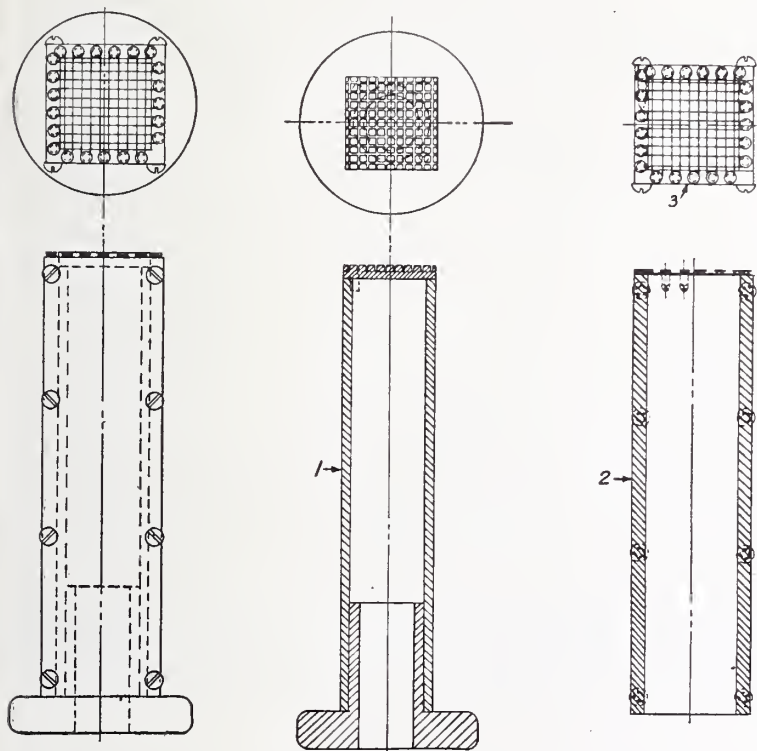


FIG. 4.

is now slipped over the "U" tube a piece of good quality rubber tube furnished with a screw cock. The level of the kerosene is now as rapidly as possible adjusted to the zero mark on the "U" tube by blowing carefully into the rubber tube and closing the screw cock at the appropriate time; this causes the kerosene to rise a considerable height in the graduated tube. The volume is now read off and the correction for capillarity applied. The data for calculating the specific gravity are now in hand.

In using such a volumeter great care must be exercised to avoid change in temperature. No claims for speed or even convenience are made for this piece of apparatus, but it has admirably



FIG. 5.

fulfilled the purpose of its construction. For good and sufficient reasons the data obtained in practice can not very well be included in this paper, and moreover such figures would not apply to any other than the bodies actually experimented upon.

Summary

1. It has been shown microscopically that pugging causes a segregation of the mineral constituents of a plastic body.
2. A method has been shown for the determination of the working pressure of pug mills.
3. Pugging causes an uneven distribution of occluded air.
4. A method has been developed that shows the actual distribution of air in a plastic body.
5. By plotting data obtained by this method the nature of air distribution is made obvious.

6. The effect of changes in pug mill set-up may at once be properly assessed.

7. The specific gravity of very small sections may be readily obtained.

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DETROIT, MICHIGAN
September 25, 1919

NOTICE.—Further discussion of this general subject is solicited. All communications should be sent to the Editor.

TWENTY-THREE TYPES OF OPTICAL GLASS

By ROBERT J. MONTGOMERY

Owing to the fact that little or no optical glass was manufactured in the United States before the European war, there is very little known about the subject in this country. Articles so far published have recorded the remarkable advance made in the technique of its manufacture and certain types have been discussed in some detail, but to my knowledge no general survey of the subject has been published. To the average mind the distinction between optical glass and other types of glass is not clear, and the divisions of the field with the limits of optical properties which may be obtained are not fully catalogued. In this paper an effort is made to classify the ordinary types of optical glass and to discuss their composition in general terms.

By the word optical we mean those glasses which are selected for certain purposes because of their behavior toward transmitted light. This behavior is primarily due to the composition of the glass and not to its shape. Practically all of these glasses are silicates. There are a few special glasses containing no silica, as borates and phosphates, but they are of minor importance as far as quantity of glass manufactured is concerned. Each constituent has an effect on the index of refraction and the dispersion of the glass, and these two properties identify the glass as being of a certain type. Glasses not called optical glass are those made to meet some other requirement than that of index of refraction and dispersion. These will include ordinary soda-lime and lead glasses, in which the composition may be changed to obtain satisfactory melting qualities, or thermometer glass, where the coefficient of expansion is important. The main difficulty in making optical glass is in obtaining the required optical properties and at the same time so combining the constituents and handling the material that a good quality of glass will result.

Our information on the subject has advanced to the point where optical properties are relatively easy to obtain, but in some

cases it has been impossible either in Europe or in this country to obtain really good glass. Certain types are of poor color and contain bubbles. Williams and Rand¹ state that the composition of the glasses made by the Bureau of Standards were based on analyses made on glasses manufactured in Europe. In "Jena Glass,"² by Hovestadt, a list of 76 glasses is given with dispersion running from 19.7 to 70.0 and index from 1.4967 to 1.9626. The composition of a few of these are given further on in the book but the information is too meager to be of value. In Doelter's "Handbuch der Mineralchemie," E. Zschimmer gives a list of 179 glasses. Both the composition and the optical properties for 87 glasses are listed. A study of this published information, combined with our practical experience in the manufacture of optical glass, brings out the following points: (1) All the glasses may be plotted on coördinate paper allowing the dispersion to be represented by the horizontal distance and the index by the vertical distance. (2) That the glasses fall into natural groups in the field plotted and may be divided into types according to composition. (3) That there are 23 ordinary types of optical glass, each type embracing a number of glasses quite similar in optical properties, composition and method of manufacture. (4) That the composition of the glasses may be divided into two divisions, (a) fundamental oxides affecting the optical properties, and (b) control chemicals which affect the melting behavior. The fundamental oxides are: SiO_2 , K_2O , Na_2O , CaO , PbO , ZnO , B_2O_3 , and so forth, while by the control chemicals are meant the proportioning of carbonates, nitrates, chlorides and sulphates or the use of As_2O_3 and Sb_2O_5 to obtain good melting conditions. In some cases the fundamental oxide may be used as a control chemical when the optical properties are not affected by so doing or when the composition may be corrected for the addition of such chemical. Plate 1 shows the fields occupied by the various types of glass with an index 1.45 to 1.800 and dispersion value from 20.0 to 70.0. These are listed in table 1. The ones marked with an asterisk are now being successfully made in commercial quantity in this country.

¹ *J. Am. Cer. Soc.*, 2, 432 (1919).

² English Translation, 26-31.

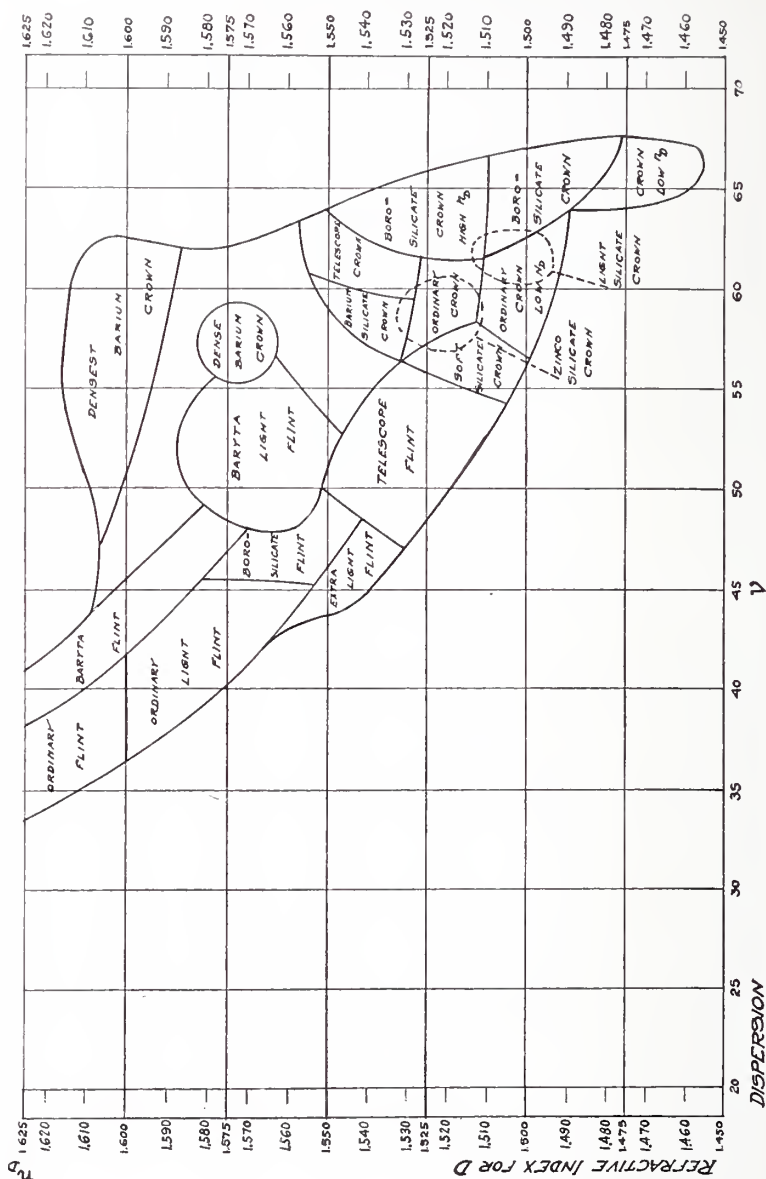


PLATE 1.—Showing dispersion and index of refraction of the types of optical glass.

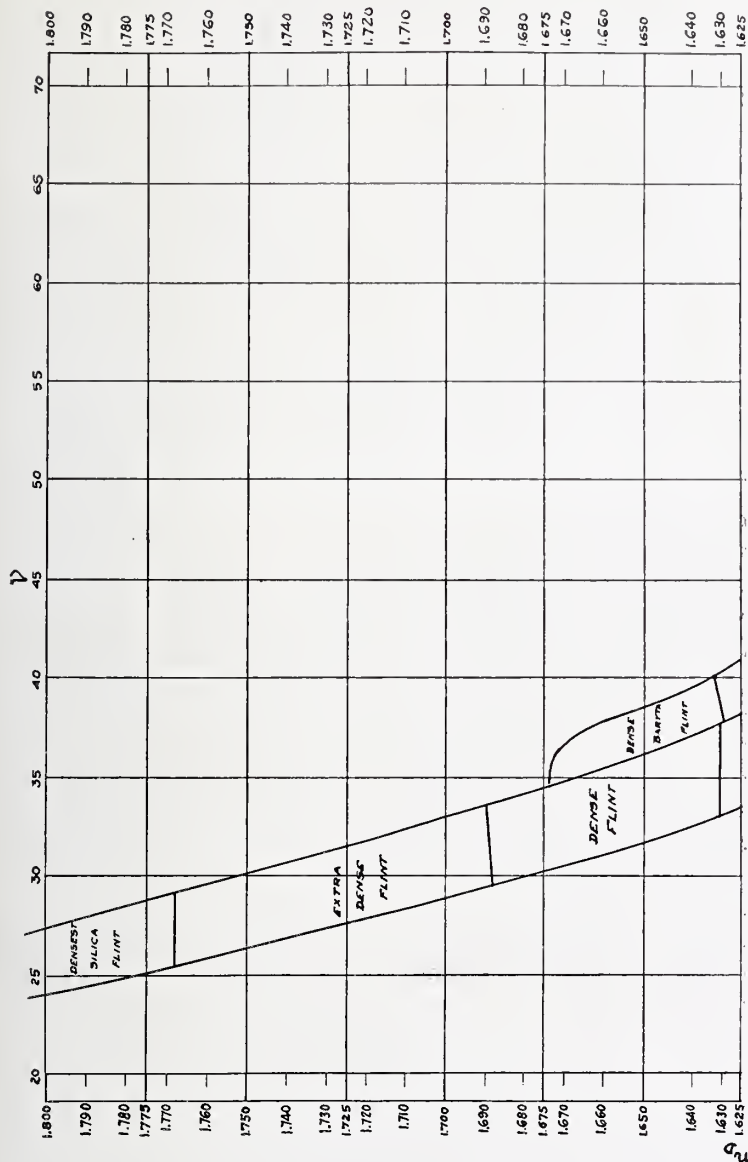


TABLE 1

| | |
|----------------------------------|--------------------------|
| 1 Borosilicate crown | *13 Baryta light flint |
| *2 Borosilicate crown high N_D | *14 Baryta flint |
| 3 Crown of low N_D | 15 Dense baryta flint |
| 4 Light silicate crown | *16 Telescope flint |
| *5 Ordinary crown | 17 Extra light flint |
| 6 Telescope crown | 18 Borosilicate flint |
| *7 Ordinary crown of low N_D | *19 Ordinary light flint |
| 8 Soft silicate crown | *20 Ordinary flint |
| 9 Zinc silicate crown | *21 Dense flint |
| 10 Barium silicate crown | *22 Extra dense flint |
| *11 Dense barium crown | 23 Densest silica flint |
| *12 Densest barium crown | |

It will be noted that we have now made in this country 12 out of the 23 ordinary types of optical glass. Most of the ones which have not yet been made have not been attempted because of lack of demand for the glass. With some we have had difficulty in obtaining quality good enough for commercial purposes, but the experience necessary for the handling of these more difficult types is rapidly being obtained.

A study of the plate shows how little of the field is actually covered by commercial glasses and that very large changes in composition are necessary to change the optical properties to any extent; that is, the index in the first decimal place and the dispersion in the tens place. At the same time it is evident that if the index of refraction and dispersion are to be kept constant for any one glass very small variation in composition will be disastrous. A variation of 0.1 per cent in the amount of the important oxides will affect the index from 0.5 to 1.0 in the third decimal place and the dispersion from 1 to 5 in the first decimal place.

Along the left side of plate 1 is the lead zone which extends from the telescope flint to the densest silica flint. This is almost a single line instead of a zone as given and shows the effect on the index and dispersion of the increase of lead from 10 per cent up to 80 per cent of the batch. This zone may be extended to an index of 1.96 and a dispersion value of 19.7. As we go to the right of this narrow zone barium and zinc are introduced, and we have dense baryta flint with about 10 per cent barium and 5 per

cent zinc, through baryta flint to baryta light flint with 15 per cent barium and 10 per cent zinc. Below these in index are the borosilicate flint, and an extra light flint where boric acid is used in place of barium. The glass containing the smallest amount of lead is the telescope flint.

The lead now disappears and, returning to the barium glasses, which have a rather high index, we have barium silicate crown with about 20 per cent barium, 10 per cent zinc and 2 to 3 per cent of B_2O_3 . The barium and B_2O_3 increase as the index increases from 1.540 to 1.61 through the dense barium crown to the densest barium crown, where the barium is about 40 per cent and B_2O_3 10 to 15 per cent. The zinc slightly decreases with these higher index values. There is a middle field which does not seem to be covered by glasses now made. Probably the reason for this is that there is no demand for the glass. In some of the densest barium glasses some Al_2O_3 is often used and may run as high as 8 per cent.

Zinc is largest in amount in the baryta light flint and dense barium crown, being as high as 15 per cent. It decreases in amount as the dispersion increases and is used in the zinc silicate crown and to a small extent (2 per cent) in the soft silicate crown and ordinary crown with low N_D .

The soda-lime field includes the ordinary crown and the ordinary crown of low N_D , while the telescope crown is a soda-lime glass containing B_2O_3 and some barium.

We now come to the glasses containing B_2O_3 in larger amounts. The light silicate crown contains from 5 to 10 per cent and as its field overlaps some of the others it is shown in dotted lines. The borosilicate crown of high N_D contains about 10 per cent B_2O_3 and is rather high in alkali. In the borosilicate crown the B_2O_3 is from 10 to 15 per cent and may contain 2 to 4 per cent of barium or Al_2O_3 . The crown of low N_D is higher in B_2O_3 and alkali and lower in CaO .

In making this survey of optical glasses only the general compositions are discussed. There is a natural field in which we normally use each constituent. This does not mean that such constituent may not be used outside of its natural field to control the optical properties or the quality of the melting. The amount

used in such cases is small and does not affect to any considerable extent the type of the glass. When it is desired to develop a new glass with new optical properties its composition can be roughly determined by interpolation between known points in the field, and the necessary chemicals are definitely shown, except in those cases where unusual materials are used.

Special glasses not containing silica, as borates and phosphates, are not considered in this paper; and a few special ones within the field given are left out, as they do not bear directly upon the general subject.

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CERAMIC ABSTRACTS

General

PATENTS

Insulator composition. F. RICHARD AND F. M. BRADY. U. S. 1,329,094, January 27, 1920. Silica and carbon with lesser quantities of alumina and ferrous oxide are mixed with water and a binder, the mass shaped and heated first to 100° F. to drive off the water, then to 800° or 900° F. to burn out the carbon then the temperature is raised rapidly until contraction ensues and finally the mass burned to incipiently fuse the ferrous oxide.

Heat insulating brick. J. C. EMLEY. U. S. 1,330,249, February 10, 1920. This is a brick particularly adapted for the outer walls of ovens, and having a vitreous or glass face and a heat-insulating backing keyed thereto. The heat-insulating backing consists of infusorial earth and a heat-resisting cement binder.

Basalt, process for the construction of monolithic structures of. F. RIBBE AND P. DHE. U. S. 1,331,377, February 17, 1920. Dams, sea-walls, piers, bridges, fortifications, etc., are made of cast basalt or other volcanic rock. Forms of brick, burned clay slabs, cast iron or very dry cement are erected and the molten basalt poured thereon. The basalt is first heated to quiet fusion and all gas bubbles allowed to escape. In order that the glass be monolithic each successive pouring must be made before the preceding one has cooled too far and thus the molten basalt remelts the surface of the previously cast material and forms an autogenous weld therewith.

Car for tunnel kilns. P. A. MEEHAN. U. S. 1,328,749, January 20, 1920. The body of this car is a single steel casting carrying a floor of refractory material. There are four independently journaled wheels which support the car through depending flanges integral with the body of the car, and open at their bottoms to receive the axles.

Kiln, down-draft. J. ELCOCK. U. S. 1,329,830, February 3, 1920. This is a round down-draft kiln having the usual bags. After the coal is coked in the fire-boxes it is said to be thrust back into the bags and burned. There are two parallel flues which cross the bottom of the kiln and open at intervals through the floor, and four auxiliary flues which connect with these and radiate to four stacks located within the kiln wall.

Kiln, tunnel. G. H. BENJAMIN. U. S. 1,329,745, February 3, 1920. This is a muffle tunnel kiln of a modified Dressler type. The heating zone of the kiln is lined with a series of independent enclosed combustion chambers, which are spaced from the side walls and the roof of the kiln. Laterally movable refractory screens are interposed between these combustion chambers and the ware. Air is allowed to enter the kiln and pass upward on either side of the combustion chambers, and thence downward through the ware. The heating is thus largely by convection. By moving the screens in relation to the combustion chambers the amount of air passing between each screen and its combustion chamber may be regulated, and also the amount of direct radiation through the screen to the ware.

Kiln, tunnel. P. D'H. DRESSLER. U. S. 1,330,433, February 10, 1920. In the Dressler tunnel kiln, the products of combustion pass from the longitudinal combustion chambers in the high temperature zone through conduit extensions in the pre-heating zone. There is often more heat remaining in the product of combustion as they pass through these conduits than is necessary to pre-heat the on-coming ware, and the latter are, therefore, often heated too rapidly. By means of the present improvement atmospheric air in regulated amounts is allowed to mingle with the hot gases at the point where they enter the pre-heating conduits.

Kiln tunnel, combustion chamber. P. D'H. DRESSLER. U. S. 1,330,432, February 10, 1920. This is a modification of the type of combustion chamber disclosed in the patent to Conrad Dressler, U. S. 1,170,428, February 9, 1916. This modification consists in perforating the outer walls of the upper and inner convection ducts which surround the combustion chamber proper. This is done, however, only at the car entrance end of the kiln where the heat of the combustion gases has been largely used up. The object of these perforations is to allow of some direct radiation from the combustion chambers proper to the ware.

G. E. MIDDLETON.

Refractories

Brick refractory for boiler furnaces. P. SCHNEIDER. *Tonind. Zeit.*, 44, 57-59 (1920).—Refractories in boiler furnaces may roughly be divided into two classes: (a) Brick which come in contact with hot gases and flames and (b) brick which come in contact with hot gases but no flames. Temperatures vary from 900°-1450° C. in different parts of the furnace. The brick in Class A must stand much higher temperatures than those in Class B. Brick having a deformation point of cones 31-33 are required for class A and cone 26 for Class B. Bricks in class A should be burned above cone 10 before putting in the furnace, and should not change more than 2 per cent in volume after they are put in the furnace. Brick with coarse grained grog or flint clay should be used in class A, as these withstand heating and cooling better than the finer grained brick.

H. G. SCHURECHT.

Silica brick from the roof of an open-hearth furnace. J. E. STEAD. *Trans. Cer. Soc.*, 18, Pt. II, 389-398 (1919).—For the purposes of comparison the brick was divided into zones. Zone A was the lower layer, 2 inches in thickness, and was that which had been heated to the highest temperature. A freshly made fractured surface appeared to be quite homogeneous but vesicular. It was light gray in color and closely resembled the fracture of gray blast-furnace slag. Zone B₁, 2 inches in thickness, was of a much darker color than zone A, but was free from unabsorbed quartz. Zone B₂, 1½ inches in thickness, was similar to zone B₁, but contained a considerable number of particles of unabsorbed quartz. Zone C, 1½ inches in thickness, had a light yellow matrix in which were embedded unabsorbed particles of quartz. Zone D corresponded closely with the appearance of the original brick; it extended from zone C to the outside of the brick, a distance of roughly 5 inches. Microscopic examination, in polarized light, of thin sections cut from the aforesaid zones revealed in zone B the frequently described structure composed of large transparent tridymite crystals; the joints between these crystals were filled with a black opaque substance. In zone A the tridymite had undergone actual fusion, the large crystals being replaced by spherules surrounded by, but not mixed with, the black opaque constituent. On cooling, the molten tridymite changed into cristobalite and, in some places, formed birefringent regions of badly developed tridymite. In zone C the large tridymite crystals continued to appear, but gradually diminishing in size and numbers according as the less heated sections are approached, until in zone D the normal structure of the original brick was encountered. Judging from the analyses it was quite obvious that floating particles of iron oxides, lime, etc., had been absorbed at the lower surfaces of the bricks. Most of these bases, after combination with some of the silica of the bricks, have ascended by capillary attraction to a distance exceeding 5 inches. The maximum amount of iron was in B₁, and the maximum of lime was in zone C. As the fusible silicates ascend upwards, the fusing point of the lower end of the brick will be raised, a beneficent arrangement, for, if the flux remained in zone A and did not ascend, the bricks would more rapidly melt away and their life be greatly reduced.

A. J. LAMBERT.

Silica materials, notes on new experiments on. A. BIGOT. *Trans. Ceram. Soc.*, 18, Pt. II, 362 (1919).—Conclusions:—(a) Raw silica materials which are too pure are not suitable for the manufacture of silica products, because they fall to powder after having been for variable periods in the Martin furnaces. Chalk flints and many types of quartz are among these too pure materials. (b) The silica materials which contain from 2 per cent to 5 per cent of a mixture of clay, iron oxide and a small proportion of magnesia and lime do not fall to powder at high temperatures in the furnaces; they are suitable for the manufacture of silica products if their expansion at 1710° C is not too great. Some quartzitic and quartzose rocks and some dense

flints are included in the class of good raw materials. (c) The silica rocks, which contain more than 3 per cent alumina become too fusible after the addition of 2 per cent lime and are not suitable for the manufacture of silica products.

A. J. LAMBERT.

Silica products, practical guide for manufacturers of. A. BIGOT. *Trans. Ceram. Soc.*, 18, Pt. II, 354-361 (1919).—Flint and too nearly pure quartzites are not suitable for the manufacture of silica products because their siliceous elements, becoming friable, lose their crushing strength and are too porous. Bigot studied a certain number of ferruginous sandstones containing from 3 to 8 per cent of iron oxide. After burning at 1710°C dark brown products were obtained, remaining compact even at the end of several days' heating at high temperature. In spite of their color, these rocks are suitable, like quartzites, for the manufacture of silica products. Until to-day no French manufacturer has employed them. To obtain suitable grains and powder, the rocks are first passed through a jaw-crusher, regulated so as to produce pieces small enough. The grinding of these small pieces is done in two pairs of cylinders which revolve in a vertical plane with the same speed in contrary directions, and their separation can be regulated at will. The crushed rocks are brought into the first pair of cylinders, which grind them, giving to the largest grains the desired dimensions; these large grains are accompanied by medium grains and by a little fine. To obtain the necessary quantity of fine a certain proportion of crushed material is caused to pass into the second pair of cylinders with slight separation. Sorting machines separate fine, medium and large; they may be conducted into appropriate silos, whence they are withdrawn for the needs of the manufacture. This grinding process is that which is adopted in works for grinding emery and abrasives; it is simple, it gives angular grains, whatever the degree of hardness of the material may be, it produces the necessary proportion of fine and the sorting machines always furnish the same classification, it is more economical than the use of 5-ton mills installed in certain works, and it abolishes the use of the tube finisher destined to produce silica flour.

A. J. LAMBERT.

Zinc furnace refractories, further notes on. J. A. AUDLEY. *Trans. Ceram. Soc.*, 18, Pt. II, 468-477 (1919).—Ferrous oxide, which is by far the most important of the fluxing materials in the ashes, in zinc retorts, forms with silica first fayalite, Fe_2SiO_4 ; this, on being absorbed by the muffle body, takes up from the latter more silica to form FeSiO_3 , the melting point of which is 1500°C , as compared with 1155° to 1075°C for fayalite. Alumina is also dissolved, and such other bases as may be at hand, the product becoming more and more viscous until it finally solidifies. The formation of a glaze or glassy coating on the outside of muffles—from the action of dust and fumes—does not prevent the entrance of furnace gases, or the exit of reducing gases or zinc vapor, but it materially retards such movements and therefore diminishes the formation of zinc dust while helping to increase the yield. The following analyses show the composition of a glaze on the body of a muffle:

| SiO ₂ | Al ₂ O ₃ | FeO | CaO | MgO | K ₂ O | Na ₂ O | ZnO | PbO | C & S |
|------------------|--------------------------------|------|------|------|------------------|-------------------|------|------|-------|
| 50.26 | 31.84 | 8.85 | 1.40 | 0.36 | 1.09 | 1.68 | 3.20 | 0.28 | 1.040 |

Natural gas and Mond gas—in spite of advantages due to homogeneous composition of the gas and the possibility of uniform heating—are by no means ideal combustibles, because they carry no dust with them. When such gases are employed for firing zinc furnaces it is desirable to remedy the deficiency by special glazing of the muffles.

A. J. LAMBERT.

Zinc retorts, notes on the microstructure of. ALEXANDER SCOTT. *Trans. Ceram. Soc.*, 18, Pt. II, 512-515 (1919).—The outer yellowish gray portion appears under the microscope to consist of sporadic quartz grains set in a matrix which is almost opaque. The matrix consists of a clear glass in which are innumerable microlites. Some of the latter appear to be sillimanite, but the majority are hexagonal zinc orthosilicate. As the blue portion is approached the latter increase in number while the amount of tridymite also becomes greater. A microsection of the blue material shows it to be partly crystalline and partly glassy. The original material of the matrix has been completely changed, the alumina having reacted with oxidized zinc to form spinel, while the silica appears partly as tridymite and partly as silicates of zinc and iron. Several syntheses of both ortho- and metal-silicates of zinc are on record, but the evidence regarding the latter is somewhat unsatisfactory. It seems probable that under the conditions obtaining in zinc retorts, zinc oxide reacts with the free silica of the retort to form the orthosilicate and not the metasilicate. In each of the cases described above, the silica was in excess of that required to form the metasilicate, yet the final zinc salt was willemite. The results obtained above are in favor of Vogt's view that the orthosilicates of zinc and iron form two series of mixed crystals, one rich in zinc and crystallizing in the hexagonal system (willemite) and the other, rich in iron and forming orthorhombic crystals (fayalite).

A. J. LAMBERT.

Coke oven walls, the corrosion of. I. The salts extracted from coal by washing. W. G. REES. *Trans. Ceram. Soc.*, 18, Pt. II, 431-434 (1919).—The salts present in coal probably have a corrosive action on the walls of coke ovens. Rees finds the salts to consist chiefly of sodium chloride and sodium sulphate. They are much reduced by the washing of the coal.

A. J. LAMBERT.

Fire brick, some criticisms by a manufacturer. G. R. L. CHANCE. *Trans. Ceram. Soc.*, 18, Pt. II, 456-467 (1919).—See *J. Am. Ceram. Soc.*, 2, 838.

A. J. LAMBERT.

Mica schist for lining cupolas and steel-converters.—P. G. H. BOSWELL. *Trans. Ceram. Soc.*, 18, Pt. II, 382-388 (1919).—In British practice the material in common use for lining such furnaces as cupolas and steel con-

verts is so-called "ganisters," which consists of a sloppy mixture of broken quartzite or ganister rock and fire clay or ground ganister. Such a mixture is used to a small extent in American foundries, but a large number of works employ a rock belonging to the mica-schist group, which is quarried in Pennsylvania and New Jersey, in each case not far distant from Philadelphia. The rock is fairly hard, and even the foliation surfaces can not be scratched by a knife without some difficulty. Nevertheless, the rock is easily split parallel to the folia and worked into the required shapes. The bulk of the rock is composed of the mineral quartz, the grains being of variable size but not drawn out into lenticles. The rock is thus rather a quartz-schist than a mica-schist. Analysis: SiO_2 , 81.58; Al_2O_3 , 10.04; Fe_2O_3 , 2.24; FeO , 0.32; MgO , 0.19; CaO , 0.22; Na_2O , 0.08; K_2O , 3.38; H_2O^+ , 1.74; H_2O^- , 0.27; TiO_2 , 0.34. The rock is built by masons into the walls of converters and cupolas, inside the fire-brick casing, in the usual way. It should be set with the cleavage edges, and not the faces forming the inner wall. Nevertheless, where the rock had been so set, the material withstood the effects of hot metal.

A. J. LAMBERT.

Cement, refractory. *Tonind.-Zeit.*, 44, 32 (1920).—The cementing action of refractory cement is not similar to that of Portland cement but its cementing action is due to the partial fusion of the mortar which in combining with the brick hold the brick together.

H. G. SCHURECHT.

PATENTS

Refractory lining. W. G. LAIRD. U. S. 1,328,380, January 20, 1920. Fire brick made of fire clay and silica may be highly refractory provided fluxing materials such as ash, alkalis, etc., do not come in contact with them at high temperatures. So-called condensed refractories such as carborundum-fused alumina, magnesia, etc., are resistant to chemical fluxing action but are very expensive. It has been attempted to bond a facing of these latter materials on a fire-clay backing, but differences in co-efficients of expansion have caused these to fail. This inventor claims to have attained success by surfacing a fire-brick furnace wall with slabs of carborundum held in place by means of locking blocks of the same material placed between the ends of the fire brick.

Refractory material and process of making it. T. SHEARD AND H. E. WETHERBEE. U. S. 1,329,434, February 3, 1920. A refractory composition is made from dolomite which is said closely to approach Austrian magnesite in composition and quality. The dolomite is crushed and burned in a rotary kiln to convert it into a mixture of calcium and magnesium oxides. The next step is the elimination of more or less of the calcium oxide, and to this end the calcined mixture is treated with HCl , or better with the waste liquor from galvanizing pickling vats, such liquor consisting of a relatively dilute solution of iron chlorides, both ferrous and ferric, together with a little free HCl .

Considering the iron as ferrous the reaction is as follows: $\text{MgO} \cdot \text{CaO} + \text{FeCl}_2 + \text{H}_2\text{O} = \text{Mg}(\text{OH})_2 + \text{Fe}(\text{OH})_2 + \text{CaCl}_2$. The calcium chloride is removed centrifugally and the residue formed into bricks or nodules and burned to about 1500°C .

It is not necessary for some purposes to remove all of the calcium oxide, and for furnace floor and wall linings a mixture comprising substantially 80 per cent magnesium oxide, and 20 per cent calcium oxide has been found satisfactory.

Refractory compounds, process of producing. U. S. 1,330,263, February 10, 1920. Calcined magnesite, an iron compound and silica are pulverized, mixed and calcined in a kiln, to cause the oxides of magnesium and iron to unite. A basic refractory is produced. G. E. MIDDLETON.

Glass

Annealing and characteristics of glass, concerning the. A. Q. TOOL AND J. VALESACK. Bur. of Standards, *Scientific Paper* 358.—The characteristics involved in annealing were investigated for a number of glasses of different composition, chiefly those produced by the Bureau of Standards at Pittsburgh. *Annealing temperature by optical method:* This method consisted of observing samples of the glass placed between crossed nicols and heated in an electric tube furnace. The double refraction remained quite constant until the "annealing temperature" was reached. At this temperature a perceptible diminution in the intensity of the light began, showing that the stresses were already relaxing at a fairly rapid rate. As the temperature rose still higher the intensity decreased at a constantly increasing rate until it had practically vanished at the "upper limit." It is advisable to use well annealed or only slightly strained specimens in these tests. The greater part of the stresses will then be due to the temperature gradient produced by heating. *Measurements of retardation:* The curves obtained indicate that the double refraction shows a distinct rise to a maximum just before it begins to fall rapidly. It crosses to negative values for a time, and then, after reaching a minimum, gradually approaches zero again. Other manifestations of this interesting transformation that takes place near the annealing temperature range in glasses lie in an apparent increased absorption of heat and in increased thermal expansivity. *Critical Range:* To determine whether any heat effect accompanied the softening of the glass, a differential thermocouple method was used. In every case the glass shows an increased absorption of heat on heating, while on cooling there is evidence of a decrease in evolution of heat in passing through the same region. These effects are not necessarily true endothermic or exothermic transformations as these terms are usually interpreted. The heat absorption and the rapid softening of the glass are allied phenomena, and it is possible to determine the annealing range by means of the heat absorption. The curve for thermal expansion gives, therefore, as Peters has shown (C. G. Peters, Meeting of American Physical Society,

| Class | Boiling H ₂ O | H ₂ O at 183° | 2N NaOH | N/10 NaOH | 2N Na ₂ CO ₃ | Boiling HCl |
|---------------|--------------------------|--------------------------|-----------|-----------|------------------------------------|-------------|
| Good..... | S (0.5) | O (15.4) | G (235.8) | Q (41.0) | D (74.1) | S (0.7) |
|  | .... | F (29.2) | P (237.3) | G (46.0) | Q (75.9) | O (1.5) |
| | A (0.8) | E (32.4) | .... | T (46.5) | .... | R (2.0) |
| | G (0.8) | B (34.8) | T | F (52.4) | E | P (2.8) |
| | C | G (35.0) | D (239.4) | L (53.0) | P (78.0) | M (3.0) |
| | O | C (38.6) | .... | D (53.9) | .... | L (3.1) |
|  | .... | A (39.8) | Q (242.9) | N (56.3) | C (83.2) | N (3.2) |
| | L | D (41.0) | S (273.6) | B (60.0) | F (83.4) | T (3.4) |
| | F (0.9) | L (60.6) | B (276.5) | E (61.8) | L (87.7) | Q (4.3) |
|  | .... | N (75.5) | N (280.9) | C (62.1) | B (90.3) | G (5.1) |
| Moderate..... | E (1.0) | Q (78.6) | E (283.8) | M (64.2) | A (92.2) | J (5.4) |
| | N (1.1) | P (85.9) | L (287.1) | A (64.4) | T (96.8) | I (5.8) |
|  | .... | .... | R (289.1) | P (65.4) | .... | D (7.2) |
| | P | .... | K (290.0) | .... | .... | H (8.0) |
| | B (1.2) | .... | C (292.4) | .... | .... | E (8.3) |
| | M | .... | M (294.0) | .... | .... | C (9.7) |
|  | .... | .... | F (312.5) | .... | .... | .... |
| | Q | .... | .... | .... | .... | .... |
| | D (1.4) | .... | .... | .... | .... | .... |
| | T | .... | .... | .... | .... | .... |
| Bad..... | I (2.8) | T (124.8) | I (343.4) | R (84.4) | G (108.1) | B (12.5) |
| | R (3.7) | M (204.8) | O (355.2) | I (90.6) | N | .... |
| | U | .... | J (364.0) | O (92.2) | .... | .... |
|  | .... | .... | A (387.6) | S (98.3) | M (145.4) | .... |
|  | .... | .... | .... | .... | O (153.3) | .... |
| | K (5.5) | R (904.6) | H (470.3) | J (111.3) | I (263.3) | F (18.0) |
| | J (6.2) | I (1435.0) | .... | H (136.8) | J (364.3) | A (31.8) |
| | H (14.4) | J (1924.4) | .... | .... | S (397.0) | .... |
|  | .... | H (3470.0) | .... | .... | R (422.5) | .... |
|  | .... | .... | .... | .... | H (600.7) | .... |

ANALYSES OF THESE GLASSES

| | K | L | M | N | O | P | Q | R | S | T | U |
|--------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| SiO ₂ | 74.32 | 68.03 | 69.84 | 68.58 | 80.62 | 66.62 | 66.80 | 75.90 | 76.10 | 67.42 | 76.20 |
| As ₂ O ₅ | Nil | Nil | Nil | 0.18 | 0.66 | Nil | 2.05 | Trace | Nil | Nil | Nil |
| Sb ₂ O ₃ | Nil | 0.45 | 1.00 | Nil | Nil | 1.80 | 1.29 | Nil | Nil | 0.65 | 0.30 |
| Al ₂ O ₃ | 2.35 | 2.62 | 0.96 | 2.90 | 2.00 | 3.11 | 2.54 | 0.24 | 0.20 | .65 | .30 |
| ZnO..... | Nil | 7.39 | 3.80 | 3.60 | Nil | 8.20 | 9.75 | Nil | Nil | 8.12 | Nil |
| CaO..... | 3.67 | 0.80 | 1.69 | 2.65 | 0.22 | 0.20 | 1.73 | 8.73 | 6.30 | 3.14 | 8.97 |
| MgO..... | 0.11 | 3.41 | 6.25 | 2.53 | .29 | 3.29 | 2.60 | 0.15 | .29 | 4.50 | Trace |
| K ₂ O..... | 1.38 | 0.30 | 0.70 | 1.29 | .61 | 1.40 | 1.75 | 7.84 | 5.60 | 3.06 | 7.62 |
| Na ₂ O..... | 17.56 | 11.18 | 11.25 | 10.01 | 3.83 | 11.76 | 7.40 | 7.29 | 11.16 | 9.92 | 7.07 |
| B ₂ O ₃ | Nil | 5.81 | 4.02 | 8.0 | 11.90 | 3.74 | 4.13 | Nil | Nil | 2.35 | Nil |
| MnO..... | 0.10 | Trace | Trace | Trace | Trace | 0.13 | Trace | Trace | 0.10 | Trace | Trace |
| Fe ₂ O ₃ | .14 | 0.20 | 0.34 | 0.20 | 0.16 | .14 | 0.17 | 0.10 | .14 | 0.21 | 0.14 |

Baltimore, December, 1918), another method of determining the highest advisable annealing temperature. *Annealing time:* The results outlined herewith all point to the desirability of as low an annealing temperature as is consistent with the efficient and rapid removal and prevention of permanent stresses. The rate of the relaxation of the stresses in the glass was determined at different temperatures by the use of two methods: first, by measuring the rate of deformation of loaded strips of rods; and, second, by determining the rate at which the double refraction in unannealed glass disappeared.

A. J. LAMBERT.

Chemical glassware, the resistant properties of. A. The resistant properties of some types of foreign chemical glassware. J. D. CAUWOOD AND W. E. S. TURNER. *J. Soc. Glass Tech.*, **2**, 219-35 (1918).—B. Further Investigation on Chemical Glassware. CONSTANCE M. M. MUIRHEAD AND W. E. S. TURNER. *J. Soc. Glass. Tech.*, **3**, 129-31 (1919).—Resistance to attack by various chemical reagents was measured in the case of 1 Japanese (K), 6 American (L, M, N, O, T, V), 5 German glasses (P, Q, R, S, U). The samples were as follows: K = Japanese; L = Nonsol; M = Insol; N = Fry; O = Pyre; T = Insol; V = Macbeth-Evans; P = Resistance "R;" Q = Kohn-Ehrenfeld; R = Kavalier; S = German, unmarked; U = Zsolua. The results of the various tests are shown in the following table in which the losses are given in terms of milligrams loss in weight per square decimeter of surface. These columns are arranged in the order of resistance to attack with the most resistant glass at the top.

These results show seven glasses in the "good" class in every test. These include three British (C, D and E), two American (L and V), and two German (P and Q). Figures on the British glasses were given in an earlier article—see *Chemical Abstracts*, **12**, 212-13 (1918). The general conclusions: (1) the zinc-aluminum borosilicates or aluminum borosilicates, especially the former, are usually the best glasses for chemical glassware, although the Macbeth-Evans glass is a zinc borosilicate with low alumina; (2) soda-lime glasses show fair resistance to water and to dilute alkali, good resistance to strong caustic alkali, poor resistance to sodium carbonate and excellent resistance to acids. This makes the soda-lime glass especially valuable for analytical work, like silica determination in steel, etc., where hydrochloric acid is used; (3) silica in glass seems to give resistance to water and acid but not to caustic or carbonated alkali; (4) boric acid, up to about 12 parts per 100 silica, increases resistance to water but lowers resistance to alkali and acid; (5) lime is, in general, not an important ingredient and should be avoided if the glass must be resistant to sodium carbonate; (6) large amounts of alkali are to be avoided because they lower resistance to water, alkali and acid; (7) alumina seems a valuable constituent in resistance glasses; (8) zinc is in high favor but specific proof of its value has not yet been shown; (9) the value of magnesia is not known but good glasses do contain considerable magnesia.

C. H. KERR.

German glassworks in March and April 1919. S. N. JENKINSON. *J. Soc. Glass Tech.* 3, 144-7 (1919).—Before the war, 75 per cent of Germany's glass products were exported. In 1913 her exports were valued at 123 million marks, compared with 103 for toys and 94 for pottery. In the early stages of the war the glass industry was practically stopped but toward the end of 1915 some glass work was started again. Preference was given to factories in small towns where there would be no competition with munitions factories for labor. Prices were exorbitant and profits were divided with the owners of shut-down plants which enabled all plants to be kept in good repair. In March and April, 1919, orders were plentiful, prices good, skilled labor available, and no stocks on hand, either at the factories or with merchants. But the business was practically at a standstill. For example, in Saxony only 8 out of 117 furnaces were operating. There is no coal to be had, and the same is true of all raw materials, foods, clothing, etc. No glass will come out of Germany for a long time, probably years, but the plants are kept in excellent condition. C. H. KERR.

Glass industry of North America. W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 166-199 (1919).—In Canada, glass making is confined to the region of the Great Lakes, at Montreal, Toronto, Hamilton, Thorold and Wallaceburg. In the U. S. the development has largely followed the discovery of natural gas wells. Different branches of the industry are somewhat as follows: Fine artistic glass in New York, lamp-blown and graduated scientific apparatus in southern New Jersey, window and plate glass in Pennsylvania and West Virginia, bottles everywhere. For decolorizers, MnO_2 is satisfactory, provided oxidizing conditions can be maintained; but this can be fully accomplished only in closed pots and in the presence of an oxidizing agent such as nitre. In tanks the conditions are reducing, and under such conditions selenium is much better. Decolorizers using selenium as a base usually contain white arsenic and a very small amount of cobalt or "powder blue." Since selenium is not a decolorizer under oxidizing conditions nitre must be absent from the batch. Consequently MnO_2 must still be used with lead glasses. Batch mixing machines are widely used and with good results. The natural gas used at glass works has 1000-1100 B. t. u. per cubic foot, against 150 for ordinary producer gas. The Frink and the Chowning regulators to control gas flow are in process of development. The Owens Bottle Company regard 17 square feet at the melting end of the tank per ton of glass melted daily as standard practice. At some plants this is greatly exceeded. At one plant 1 ton per 11 square feet and at two others 1 ton per 8 square feet were found to be satisfactory. Tank depth varied considerably from 3 to 5 feet. H. L. Dixon regards $3\frac{1}{2}$ feet as most suitable in general. Window glass tanks seem to be consistently deeper than other tanks and in the plants visited the depth was about 5 feet. Tank furnaces only 10 feet wide were found to be too narrow, the regenerators becoming overheated. Usually the breadth is about two-thirds of the length. Tank blocks in America show

considerably greater life than those in England. There are three chief causes—(1) the use of soda ash in the batch—in window glass plants where salt cake is used the life is only about 6 months; (2) the use of less CaO in American glass; (3) cooling by air or water. In pot furnaces the universal practice is to use regenerators. Some 20 years ago there was a craze for recuperators but they were not successful. Day tanks are quite common, usually being employed for special purposes, such as the melting of comparatively small quantities of resistance glass. Pyrometers are used in practically every American factory in marked contrast to their absence in English factories. Although there are some hand-operated plants, America is pre-eminently the home of machine-made bottles and jars. The Owens, Graham (or Owen's A. W.), Hartford-Fairmont Wide Mouth, O'Neill, W. J. Miller, Edward Miller, Lynch No-Boy, Cox, and other machines are briefly discussed. Semi-automatics are also referred to. In electric light bulbs, 3 large companies make 200,000,000 per year. Both hand and machine methods are used. American hand practice with a shop of three men is not equal per operator to the English production where the worker gathers, marvers and blows. Machine production seems destined to replace the hand-work. The Westlake machine is most prominent but it may be superseded by something simpler. Some details regarding the making of glass tubing and rod, chemical and scientific glassware and optical glass are given. In refractories the tendency seems toward thinner tank blocks. Blocks as thin as 8 inches are giving good service, usually with the aid of cooling devices, either air or water. The absence of German clay in America is, in many plants, regarded as a great handicap but in many cases American clays give excellent results. In pot drying great attention is now being given to humidity. American factories are employing chemists and physicists at a greater rate than in England. Colored glass for artistic ware is much inferior to the English and not in great demand. The sheet glass process of the Libbey-Owens Window Glass Company, at Charleston, West Virginia, is in successful operation.

C. H. KERR.

Great Britain, glass trade in. London *Daily Mail*, Feb. 3rd.—British makers are laying themselves out to meet the demand for glass and big strides are being made, but notable extensions of plant are hampered by building difficulties. Even the largest firms in the north of England can not keep pace with the orders. Both bottle and sheet glass makers are establishing themselves strongly in the south. The largest of these, the Willesden Glass Co., Ltd., has a first unit in operation capable of an annual output of 10,000,000 square feet of sheet glass. Big extensions, to include machinery, as experience warrants, are under construction. The Belgian hand-blown process is being used with 20 per cent of skilled Belgian workers. British apprentices are being taken on. Most of the present output is for home buyers, but exports are going as far afield as Siam and China. Besides Great Britain's demands it is estimated that France will have to import about 200,000,000 square feet of sheet glass per annum for some years to come. Meanwhile Great

Britain is importing large quantities of glass, especially American tumblers and bottles. The table glass trade on the Tyneside still flourishes and extensions are proceeding at Gateshead.

A. J. LAMBERT.

Glass for white flint medical bottles. *Schnurpfeil's Review for Glass Works*, 3, No. 34, 535 (1919).—Sand 100, carbonate of soda 32, saltpetre 2, lime 24, arsenic 0.5, manganese 0.25.

R. J. MONTGOMERY.

Lead glass, dark green of best quality. *Schnurpfeil's Review for Glass Works*, 3, No. 34, 535 (1919).—Sand 100 pounds, potash 33 pounds, nitrate of potash 6 pounds, red lead 55 pounds, bichromate of potash 10 ounces, oxide of copper 20 ounces, oxide of iron 12 ounces.

R. J. MONTGOMERY.

Lead, solubility of, in fritted glasses. *Schnurpfeil's Review for Glass Works*, 3, No. 34, 539 (1919), from *Keram Rundschau*.—The solubility of lead in fritted glasses was studied. 817 silicate frits and 560 boric acid silicate frits were tested in a 4 per cent vinegar solution. In lead silicates the resistance to the reagent increased with the silica content up to $\text{PbO} \cdot 2.5 \text{ SiO}_2$, between which and $\text{PbO} \cdot 3.75 \text{ SiO}_2$ it diminishes, rising again beyond that stage. Only frits containing solely lead, alumina and silica were vinegar-proof, although a number of others were very good. Frits containing boric acid but no alumina were very soluble. Zinc substituted for alumina increases solubility.

R. J. MONTGOMERY.

Philippine raw materials for glass making. T. DAR. JUAN. AND V. ELICANO. *Philippine Journal of Science*, 14, 465-79 (May, 1919).—Attempts made some years ago by private concerns to make glass from materials found in Pampanga and Tarlac resulted in failure. In the Philippines there is now only one glass factory, a bottle plant, which runs intermittently and falls far short of supplying the demand. This plant is at Santa Ana, Manila, and only cullet is melted. There is a large demand for bottles, glasses, and lamp chimneys which is met by imports from Japan chiefly. Deposits of limestone and sand have been investigated and analyses show an abundance of good limestones and some good sand available. The quartzose beach is sand believed to be the best. Alkali would be obtained by the evaporation of sea water. A large number of experimental glass batches, using only native materials, were made up and bottles thus produced were found to give satisfaction in service. In considering the establishment of a glass works here the following should be considered: (1) Coal is expensive but coconut shells may prove practical as fuel; (2) skilled labor would be very scarce and machine methods therefore most desirable—possibly glass blowers from Japan might be brought in more economically. The Bureau of Science in Manila will gladly give any possible help.

C. H. KERR.

Refraction of transparent solids, indices of. CH. FABRY. *Jour. De*

Phys. 9, 11 (1919), from *Amer. Jour. of Science*, 19, No. 290, 148 (1920).—An immersion method is described by which the indices of refraction for monochromatic light may be measured to one or two units in the fifth decimal place on specimens having surfaces which may not be modified or which are unpolished and irregular.

R. J. MONTGOMERY.

Research in glass, the year's progress under the auspices of the Glass Research Delegacy. W. E. S. TURNER. *J. Soc. Glass. Tech.* 3, 132-44, (1919).—The report is for the year ended March 31, 1918, the third year of the Delegacy. There has been much difficulty in securing funds and suitable accommodations to carry on the work. During the year 151 cases of inquiry have been handled, including 80 that required no experimental work, 58 that required the examination of raw materials and the study of problems in glass manufacture and 13 that involved determining physical properties of glass. The educational work is proceeding well in spite of the handicaps.

C. H. KERR.

Tank furnaces, note on the preliminary firing of. ELBERT E. FISHER. *J. Soc. Glass Tech.*, 3, 147-8 (1919).—The author recommends maintaining the empty tank at the highest possible temperature prior to charging. This favors the development of sillimanite in the blocks and increases resistance to corrosion. An actual schedule of heating follows: Aug. 12, light fire in checkers; Aug. 13, light fires in side burners; Aug. 15 (6 A.M.), 200° F.; Aug. 16, 350°; Aug. 17, 500°; Aug. 18, 700°; Aug. 19, 900°; Aug. 20, 1125°; Aug. 21, 1350°; Aug. 22, 1550°; Aug. 23, 1775°; Aug. 24, 2000°; Aug. 25, 2200°; Aug. 25 (6 P.M.), 2650°; Aug. 26, 2700° F. Filling in with cullet was then started, followed by batch and cullet as usual. The size of the tank was, melting end, 20½ × 14 feet inside; output, 40-45 tons per 24 hours. Heated up in this way the life is several months greater than when cullet is added prior to heating.

C. H. KERR.

Glassworks furnaces and gas producers, some recent improvements in the designs of. J. S. ATKINSON. *J. Soc. Glass Tech.*, 3, 148-166 (1919).—The Chapman agitator for producers has proven very satisfactory and much superior to producers without mechanical agitation. The advantages of the Chapman are (1) from 50 per cent to 100 per cent increased producer capacity; (2) gas of more constant B. t. u. value is made; (3) the calorific value is increased at least 10 per cent; (4) hand poking is practically eliminated; (5) total labor requirements are greatly decreased—it is often possible to reduce by one-half the number of producers required; (6) the uniformity of the gas permits close regulation of furnace air supply and a minimum of excess air. The Stein type recuperative pot furnace has been very successful at Joudaille and Triquet's works, near Paris. The furnace is described and illustrated. An 8-pot furnace costs \$7,000-\$8,000, excluding gas producer. Fuel consumption was 37-46 per cent of the weight of glass melted.

C. H. KERR.

PATENTS

Sheets of glass, method and apparatus for drawing continuous. J. P. CROWLEY. U. S. 1,328,268, January 20, 1920. Molten glass flows from a tank to an adjacent shallow drawing chamber in which is mounted a gathering roll, preferably of clay. This roll, which is partly immersed in the glass, rotates and carries with it for about a quarter revolution a film of glass which is fed off horizontally through rollers.

Glass-molding apparatus. E. T. FERNGREN. U. S. 1,328,273, January 20, 1920. Molten glass is fed from a tank outwardly and downwardly through a duct, the upwardly disposed outlet orifice of which is below the level of the glass in the tank. A rotary mold-carrying table moves over this orifice in such a manner that successive blank molds are filled as their bottoms register with the orifice; the glass being forced upward because of the hydrostatic pressure of the molten glass. When large articles are being molded the rotation of the table is step-by-step, but in the case of small articles the flow of the glass is rapid enough to permit of constant rotation. As the blank is carried by the table the blank mold sections are automatically removed and the mold sections proper positioned about the blank. An orifice is then forced down on the blank and the articles blown. It is then automatically discharged upon a conveyor.

Glass bulbs, method of sealing. A. J. LOEPSINGER. U. S. 1,328,530, January 20, 1920. Frangible glass bulbs containing gases dissolved in liquids designed for use in sprinkler systems have their necks sealed without driving off the gases from the solution by immersing the bulbs during the sealing operation in a heat-conducting liquid such as water or mercury.

Glass-drawing apparatus. H. K. HITCHCOCK. U. S. 1,328,673, January 20, 1920. This is a combined drawing and take-down apparatus. It comprises a tilting frame pivoted near the bath of glass from the upper end of which the bait is raised. Air is supplied to the bait through two jointed hollow arms. When the cylinder is drawn the frame swings about its pivot and brings the cylinder into a horizontal position.

Glass, paddle or plunger for molten. H. E. PEILER. U. S. 1,328,799, January 20, 1920. A body of refractory clay is reinforced by a metallic core. This core is kept cool by circulating air or other cooling fluid through passages therein.

Staining glass, method of. J. W. HASBURG. U. S. 1,328,833, January 27, 1920. Glass or ceramic ware is stained by applying a porous foundation coating to the surface thereof, then applying a coloring material upon this coating in a condition which permits it to penetrate the coating and firing.

Sheet glass, apparatus for making. J. WHITTMORE. U. S. 1,328,864, January 27, 1920. One method of making sheet glass consists in drawing the glass upwardly from a pool in a continuous sheet and over a binding roll of wood. In order to prevent overheating of the roll, moisture is supplied continuously to its surface by running it in a trough of water. It has been difficult to apply this moisture uniformly, however; drops have collected on the roll, which have turned to steam under the glass sheet, causing irregularities in the finished glass. To obviate this objection this inventor places a suction box along the surface of the roll between the water trough and the point where the glass sheet contacts. This suction box removes the excess moisture and leaves it uniformly distributed.

Glass cylinders, apparatus for drawing. H. J. WALTER. U. S. 1,329,065, January 27, 1920. Grooved guides are provided immediately above the glass to direct the movement of the bait which is flexibly suspended from the hoist cable, and prevent lateral or swaying movements when the bait is entering or leaving the glass.

Glassware, machine for making hollow. S. D. OLSEN. U. S. 1,329,253, January 27, 1920. This is an automatic hollow article or bottle-blowing machine in which the blank is formed in one mold and thus transferred to a blow-mold for the final shaping. These molds are arranged upon a rotary table which rotates with a step-by-step motion. This invention relates particularly to the automatic means for effecting the transfer of the blanks from the blank-molds to the blow-molds.

Glass, apparatus for manufacturing articles of. W. J. MILLER. U. S. 1,329,624, February 3, 1920. This machine for pressing glass articles comprises an intermittently rotating mold support having means for locking it between movements; means for discharging the finished glass articles from the molds, and means for supporting the molds during the pressing or forming operation so as to relieve the mold support and its associated mechanism from strain.

Glass, machine for cleaning blow-pipes for. A. A. KRIDER. U. S. 1,329,841, February 3, 1920. Blow-pipes are fed transversely of a rotor having cutting blades which removes the glass from the ends of the pipe.

Glass-discharging mechanism. J. RAU. U. S. 1,329,851, February 3, 1920. Discharge of molten glass from the spout of a glass tank into molds is effected by having a reduced discharge chamber with a suitable mouth or discharge outlet into which chamber the desired quantity of glass is suddenly forced from an adjacent chamber by means of plunger, which causes glass in discharge chamber to rise very suddenly and overflow into the waiting mold.

Glass cylinders, apparatus for drawing. W. E. SLOPPY. U. S. 1,330,097, February 10, 1920. Means are provided which act automatically to supply air in increasing volume and under a constant pressure during the drawing operation. At the beginning of the draw and during the period in which the cap of the cylinder is to be formed, the apparatus may be manually controlled so that any desired degree of pressure may be produced within the cap in causing expansion thereof to the desired diameter.

Quartz glass, method of building up objects of. W. S. QUIMBY AND F. W. ROBINSON. U. S. 1,330,611, February 10, 1920. A heated nucleus is brought into contact with a mass of quartz powder, and rotated therein so that an accretion of powder is caused to surround and adhere to the nucleus. The whole is then reheated to fuse the powder and incorporate it with the nucleus. During this operation the plastic work is elongated. If the article is a tube compressed air is used as an internal support for the walls.

Glass-blowing machine, automatic. F. R. HOFFSTATTER AND F. J. RIPPE. U. S. 1,330,70, February 10, 1920. This is a machine for blowing small incandescent lamp bulbs from glass tubing. Successive portions of the tube are automatically fused and blown and the completed bulbs detached and the ends of the tube shaped for the formation of the next one.

Glass-working machines, adjustment and indicator for. W. H. HONISS. U. S. 1,331,467, February 17, 1920. The machine illustrated is one having a paddle or plunger which is swung back and forth and raised and lowered in the molten glass in the outlet spout of a melting furnace to cause the molten glass to flow intermittently from the discharge end of the spout. Means are provided for varying the amplitude and dip of this paddle and indicating means for showing the degree of adjustment. G. E. MIDDLETON.

Glassware, mold for. K. E. PEILER AND W. A. LORENZ. U. S. 1,331,471, February 17, 1920. This is a sectional mold for glassware which may be swung open and closed with one hand.

Glass-shaping machines, transfer mechanism for. K. E. PEILER AND E. H. LORENZ. U. S. 1,331,472, February 17, 1920. Several sets of molds are carried on a rotatable table, each set comprising a blank mold and a blow mold for shaping the bottles or other ware. The blanks or parisons are formed in a blank mold, and then automatically transferred to an adjacent blow-mold in which the bottle is completed.

Method of and apparatus for drawing sheet glass. I. W. COLBURN. Reissue 14,794, January 27, 1920. Original 1,160,692, November 16, 1915. G. E. MIDDLETON.

Whiteware and Porcelain

Apatite substituted for bone ash. B. N. DAVIS. *Trans. Ceram. Soc.*, 18, Pt. II, 378-381 (1919).—Tests were made with typical bone china bodies substituting apatite for bone in the following proportions:

| | 1 | 2 | 3 | 4 |
|-----------------|----|----|----|----|
| Apatite..... | 42 | 39 | 35 | 32 |
| Feldspar..... | 15 | 16 | 17 | 19 |
| China clay..... | 33 | 34 | 34 | 35 |
| Flint..... | 10 | 11 | 14 | 14 |

The material was ground for from ten to forty-eight hours in a ball mill, and worked by casting and plastic methods into a series of test cups. It showed excellent casting properties and plasticity, both being improved by the lengthening of the grinding period. The bodies were burnt to cones 8, 9 and 12, and greatest translucency was developed in 4 at cone 9. All pieces at cone 12 showed deformation and bloating. In color the ware had a slight greenish tinge, giving it a certain distinction. Similar results were obtained in tests carried on by another worker with bodies in which no flint was used. In the discussion emphasis was laid on the fact that working with small trial pieces is not very satisfactory for bone china bodies, since compositions that give good results in small pieces are very liable to warp and deform when made up into commercial wares.

A. J. LAMBERT.

Bodies, notes on the preparation of. R. L. JOHNSON. *Trans. Ceram. Soc.*, 18, Pt. II, 321-326 (1919).—Comparison of cylinder versus pan milling of flint. It is quite possible to produce equally as good finished material from cylinders as from pans. The amount of steam used per ton of flint ground is higher in the case of pans, partly because the load with cylinders is more uniform and partly because the gearing absorbs more power. Liability to breakdown is considerably higher and more serious in a pan mill. The labor and management cost under equal conditions is greater in the cylinder mill, but this is generally counter-balanced by the cylinder mills having more labor-saving appliances. For cylinders it is preferable to crush the flints to the size of beans, but this is unnecessary for the pans. In capital outlay, the cylinder mill has the advantage. The cost of grinding on a pan mill is not more than the cost of obtaining the same degree of quality and fineness by grinding on cylinders. Where the standard is less finely ground finished material which can be obtained by lawning, the cylinder methods will be the more economical. The higher percentage of milled materials and the finer they are ground the whiter, freer from specks and the more china-like will be the body, speaking generally. Both ball and china clays should be blunged to a thick slip, but not overblunged. The flint and stone ought to be washed fine and aged as much as possible in a slip state and used for mixing in the body at not less than 32 ounces to the pint. Scraps should be added in a slip which is heavier to the pint than the newly mixed body. A. J. LAMBERT.

Bone china body, recent research on the. J. W. MELLOR. *Trans. Ceram. Soc.*, 18, Pt. II, 497-509 (1919).—There is also a reaction between water and bone-ash which forms soluble acid calcium phosphates, or even phosphoric acid itself. As a result of these changes, the body materials acquire a far greater plasticity than they would otherwise possess. The longer the materials have been associated with water during their preparation, the more "buttery" the body. Bone-ash commences to break down and give off P_2O_5 gas at a temperature about $20^{\circ}C$ above what the fireman regards as a good finish. There is not very much more than one or one and a half per cent of iron in a bone china body, but if we find in a bone china body indications of the formation of greenish blue, blue, and brown colors, there is a probability that iron phosphate has been formed. The presence of carbon and insufficient air in the oven favor the formation of iron phosphate by enabling the transformation to take place more quickly at a lower temperature than it otherwise would do. Steam from damp saggars, etc., may act in the same way by preventing the access of air to the ware at the right time. Bone-ash may contain carbon under such conditions that it does not burn out readily. Another form of carbon burns out of the body readily, and gives very little trouble in the biscuit firing. The greenish blue color can be obtained at the ordinary temperature of a china biscuit oven, altogether apart from the atmosphere and of carbon. The range of good body composition is very narrow, being close to 47 bone-ash, 23 china clay, 30 Cornish stone. There is a bigger margin of safety with variations in the proportion of bone than there are in the proportion of either stone or clay. The smaller the proportion of stone and the greater the proportion of clay, the greater the tendency to produce blue or brown china. But by raising the stone too much, the bodies are made to blister or bloat. The mere change from a soft to a harder variety of stone may give a perfect body a tendency to form blue china; or the converse change from a hard to a softer variety may make a perfect body liable to blister. A variation in the proportion of water in the same variety of stone may also upset the balance. The same body may produce blistered, blue and perfect china. The blistered body signifies too much stone or too soft a stone, and the blue china too little or too dry a stone. Blue china may oxidize in the enamel kiln and produce brown stains. The condition of the white iron phosphate in the body may be so sensitive that it oxidizes to the brown form merely by exposure to the air. Brown ware is very liable to spit in the enamel kiln. The spits are particularly prolific where the brown occurs, but not in the blue parts. The region for a satisfactory body is very restricted, being bounded one side by the zone of crazing, and on the other by a zone of blistering or bending. A. J. LAMBERT.

Borates of lead, note on the. H. V. THOMPSON. *Trans. Ceram. Soc.*, 18, Pt. II, 510-11 (1919).—Lead polyborate, $2PbO, 3B_2O_3, 4H_2O$, cannot be obtained by precipitation of a lead salt with borax in excess as stated by Soubeiran, (*Jour. pharm. chim.*, 11, 31 (1825)). It is doubtful whether there

is such a compound. $\text{Pb}(\text{BO}_2)_2\text{H}_2\text{O}$ is precipitated from solutions of lead salts by concentrated borax solution in excess and not $2\text{PbO}_3\cdot 3\text{B}_2\text{O}_3\cdot 4\text{H}_2\text{O}$. The existence of $\text{PbO}_3\cdot 3\text{B}_2\text{O}_3$ as a fusion product of lead oxide with excess B_2O_3 was confirmed.

A. J. LAMBERT.

Casting of heavy pottery. B. J. ALLEN. *Trans. Ceram. Soc.* 18, Pt. II, 363-377 (1919).—Cored or open molds are fitted with airtight casings arranged so that the air can be removed from the space between the plaster and the casing by means of an air pump. If the thickness of clay is abnormal, or a quick casting is required, pressure may be applied to the slip in addition to the vacuum. Here the funnels are fitted with full bore stop-cocks and reservoirs through which the slip passes to the mold and below the stop-cocks a connection to an air compressor. When the mold has been filled and working for a short time under vacuum the stop-cocks to the funnels are closed and compressed air admitted to the top of the slip. The advantages of applying compressed air to one side molds is not so important as its application to cored molds. When articles with both thick and thin parts are to be cast the pressure is applied at the thin parts. The pressure forces the clay slip through the thin part and keeps the way open until the heavy part will take no more, then fills up to the inlet feed and makes a sound piece. This type of mold is very suitable for lining the inside of a refractory pot with special material. For example, zirconia may be cast on the core by dipping, and then placed in the outer mold and the fire clay or other refractory mixture cast on it. In casting a covered glass pot the vacuum chamber at the sides only extends a short distance from the bottom. The object is to permit of the base and sides near the bottom being cast thicker than the top. The superfluous slip from the mould is sucked out by a vacuum pump. The vacuum process can be simplified and made adaptable to various sizes of articles by the use of a vacuum box. The molds are constructed with a framework of wood arranged with runners so that the mold can slide into the vacuum box like a drawer into a chest. The joint at the front is made with a soft rubber washer tacked to the case. This arrangement permits a number of molds being put into one vacuum chamber. A 38-inch glass pot can be dealt with in a similar way, but in the case wheels would be fitted to the bottom of the mold to permit easy withdrawal. In casting enameled fire clay lavatories under vacuum, the white engobe can be filled into the mold and cast up to any desired thickness, then the superfluous material run off and the fire clay run in and cast up solid. In the case of a bath mold a ferro-concrete chamber with metal front and door are used, and the mold supported on "T" iron bearers which act as runners. The plaster mold is framed in wood having suitable apertures to expose the plaster and does not vary much from a mold for pressing baths as far as the outside mold is concerned. When cast up the mold is withdrawn and the core removed, then the front and side molds, leaving the bath resting on the base mold. For casting insulators in multiple molds by the vacuum process a two-piece plaster mold is used and the cores, with

screw thread complete, arc of porous pottery, also cast. The cores need not be porous if a high vacuum is used. Specially designed metal cores with a plaster filling may be used. The advantages of the vacuum process for certain refractories is that it is possible to get a density under vacuum and pressure that is impossible by ordinary pressing or by casting without a vacuum. The great advantage, especially for high tension insulators, however, is in the homogeneous structure produced. A. J. LAMBERT.

Nigerian pottery. D. ROBERTS. *Trans. Ceram. Soc.*, 18, Pt. II, pp. 340-353 (1919).—The use of the potter's wheel and spinning cone have either been lost or were never known amongst the natives of West Africa, although almost every town has its potters. For shaping, an open vegetable gourd or calabash is selected according to the size of pot required and the purpose for which it is intended. To make the bottom part, a piece of clay is battened on and then allowed to dry until the next day, when it is turned up and the top part built to completion. The firing is done in the open. A mound of clay pots intermixed with dried leaves, faggots, wood, corn-cobs, etc., is burnt off in about 12 hours. Those pots which are intended for cooking purposes are dressed while still hot with a liquid preparation made from resinous leaves; this treatment makes them fairly watertight by sealing the pores of the ware.

A. J. LAMBERT.

Brick and Tile

Lime hydrate for chimneys. M. BULNHIM. *Tonind.-Zeit.*, 44, 113-114 (1920).—The purpose of this investigation was to compare the compression and tensile strengths of mortars containing Portland cement with those not containing cement. A mortar composed of 1 part lime and 4 parts sand was compared with another composed of 1 part Portland cement, 2 parts lime and 7 parts sand. The results which are tabulated below show that the mortar containing cement is superior with reference to strength.

| | Tensile strength kg./cm ² . | | | | Compression strength kg./cm. ² | | | |
|-----------------------------------|--|------------|-----------|------------|---|------------|-----------|------------|
| | 7 days | 28 days | 1 year | 2 years | 7 days | 28 days | 1 year | 2 years |
| Mortar No. 1 (no cement)..... | 0.31 | 0.42 | 1.62 | 3.90 | 1.08 | 1.22 | 6.23 | 7.66 |
| Mortar No. 1 (with cement)..... | 1.90 | 2.37 | 4.15 | 4.46 | 8.30 | 14.02 | 42.88 | 49.16 |
| Brick work with No. 1 mortar..... | .. | .. | .. | .. | 134.75 | 135.40 | 154.15 | 160.35 |
| Brick work with No. 2 mortar..... | .. | .. | .. | .. | 208.80 | 228.05 | 279.50 | 288.95 |

H. G. SCHURECHT.

Hollow block question, the solution of the. *Tonind.-Zeit.*, 44, 75-76 (1920).—Hollow block have not been very popular, due largely to the fact

that too much mortar is required in laying them. An auger machine which will make hollow blocks, closed on all sides, has recently been invented. This auger machine works continuously, making 15,000 brick per eight-hour day.

H. G. SCHURECHT.

Rough tile for walks. B. L. *Tonind.-Zeit.* 44, 95 (1920).—It was found that in many cases the tile used for sidewalks became very smooth and slippery especially in rainy weather. To make a rougher brick coarse grains of grog were added to the tile in making them. These tile had an extremely rough surface at first but after some time also became smooth and slippery. It was observed that porous tile became less slippery than the hard burned tile but these did not withstand the action of frost. It was therefore recommended that a mixture of soft and hard-burned grog be added to the body in making sidewalk tile. Such a tile would wear unevenly and hence have a permanent rough surface.

H. G. SCHURECHT.

Standardization of brick. *Tonind.-Zeit.*, 44, 93-94 (1920).—Building brick constitute burned brick made of clay, argillaceous earth, clay partly replaced by sand, broken quartz or calcined clay. They must have a crushing strength of at least 100 kg./cm². These brick are classified as follows: (a) Clinker having a compression strength of 350 kg./cm²; (b) hard burned brick having a compression strength of 250 kg./cm²; (c) building brick, class 1, 150 kg./cm², and (d) building brick, class 2 having a strength of 100 kg./cm². The size should be 25 cm. long, 12 cm. wide and 6.5 cm. high. If it is impossible to make the brick this size the ratio of length, width and height should be 4 : 2 : 1. The limit of absorption for clinker should be 5 per cent hard-burned brick 8 per cent and for class 1 and 2 of building brick the upper limit of absorption is not limited but as a rule it is above 8 per cent. All brick should stand the freezing test. In this test the brick are frozen 25 times in water to -4° C for a period of 4 hours.

H. G. SCHURECHT.

PATENTS

Brickmaking machine. C. CROUCH. U. S. 1,331,323, February 17, 1920. A series of brick molds are connected by an endless flexible chain and passed in a vertical plane intermittently beneath a hopper of plastic clay. As each mold is positioned beneath the orifice of the hopper it is provided with a pallet; clay is forced into the mold by means of a plunger, and the mold then moved on to the next position. A second plunger thereupon extrudes the bricks still upon the pallet, which, being yieldingly supported, descends with the plunger and bricks, and the whole is carried off down an inclined runway. Meanwhile a second mold is being charged. The molds in the series are normally spaced apart by several links of the chain. There is enough slack in the chain, however, to enable the charging and discharging molds to be in abutting relation. Power is applied through the charging mold which pushes the abutting discharging mold and pulls the rest of the series.

G. E. MIDDLETON.

ACTIVITIES OF THE SOCIETY

New Members Received during April

Resident Associate

- Barth, Victor, 128 Bridge St., Great Barrington, Mass., Enameler, Stanley Insulating Company.
- Becque, J. H., Pittsburgh, Pa., Industrial Fellow, Mellon Institute.
- Bour, Laurence J., Scranton, Pa., President, L. J. Bour Refractories Company.
- Brown, Tom, 217 Dock St., St. Louis, Mo., Enameler, Buck Stove and Range Company.
- Cooper, George W., Room 608, 19 Liberty St., New York City, Publisher *The Glass Industry*.
- Griffith, R. E., 670 Bullitt Bldg., Philadelphia, Pa., Manager Refractories Sales, E. J. Lavino Company.
- Guenther, Emil B., 351 S. Negley Ave., Pittsburgh, Pa., Harbison-Walker Refractories Company.
- Guthrie, Chester, Hillsboro, Ill., Pottery Foreman, Eagle-Picher Lead Company.
- Herrell, Carson, Kokomo, Ind., Secretary-Treasurer, Kokomo Sanitary Pottery Company.
- Hogenson, E., Jr., 1421-41 South 55th St., Cicero, Ill., Secretary-Treasurer, Chicago Vitreous Enamel Products Company.
- Holstein, L. S., Palmerton, Pa., Chief, Testing Department, The New Jersey Zinc Company (of Pa.).
- Hults, Eugene A., Trenton, N. J., President, Ceramic Equipment Company.
- Lyon, P. W., 1332 Frick Bldg., Pittsburgh, Pa., Special Representative, American Sheet and Tin Plate Company.
- Storey, O. W., Madison, Wis., Metallurgist, C. F. Burgess Laboratories.

Foreign Associate

- Bodin, Victor, 6, rue Jean Jacques Rousseau, a Ivry (Seine) France, Directeur du Laboratoire du Comptoir des Fabricants de Produits Refractaires.
- Coad, Pryor, E. A., Teddington, England, National Physical Laboratory.

Corporation

- Philadelphia Quartz Company, 121 South Third St., Philadelphia, Pa.
- U. S. Smelting Furnace Company, Belleville, Ill.

Meeting of the Pittsburgh District Section

The Pittsburgh District Section held its spring meeting in the Chamber of Commerce Auditorium, Pittsburgh, on April 20th, 1920, at 2.30 P.M., Chairman Peregrine presiding.

The Chairman expressed the wish that all members of the American Ceramic Society in the Pittsburgh District be urged to join the Section. A cordial invitation to join this Section is extended to all members of the parent Society in this district. One dollar sent to the Treasurer, Mr. Thomas H. Sant, John Sant & Sons Co., East Liverpool, will assure your being sent notices of future meetings.

The following interesting program was presented:

"A Study of Spalling," R. M. Howe, Mellon Institute.

"Corrosion Tests for Glass Pot Mixtures," D. H. Fuller, U. S. Bureau of Standards, Pittsburgh.

"Pyrometric Practice," Dr. Paul B. Foote, U. S. Bureau of Standards, Washington, D. C.

The discussion on the last paper was led by Professor H. S. Hower, of Carnegie Institute of Technology, and an instructive symposium on the subject was held.

At 6.30 a farewell dinner was given in the Chamber of Commerce dining room to A. V. Bleininger, who is to be transferred to Washington. Hearty tribute was paid by the speakers to Mr. Bleininger as a man, as a scientist, and as a practical aid to the ceramic industries of this district. Dr. Tillotson introduced the toastmaster, Francis W. Walker, Sr., who reminded the Section that Mr. Bleininger was one of the founders of the Society. L. E. Barringer, of the General Electric Company, spoke of Mr. Bleininger's career in college and complimented him on his never-failing kindness. Mr. W. E. Wells told "What the pottery industry thinks of Bleininger," and his remarks left little doubt of the high standing of Mr. Bleininger among the pottery men of this district. Mr. W. L. Smith spoke in behalf of the United States Potters' Association and also paid the highest tribute to Mr. Bleininger.

Everyone present left feeling that the removal of Mr. Bleininger from Pittsburgh is a distinct loss to the ceramic industry as well as to the scientific circles in this section.

C. C. VOGT, *Secretary*.

Meeting of the Chicago Section

One of the most successful meetings ever held by the Chicago Section of the American Ceramic Society was that which occurred at the dinner arranged by the above Section at the LaSalle Hotel, Chicago, on Tuesday evening, April 20.

It happened that the Illinois Clay Manufacturers Association was holding its forty-second annual convention at the same hotel on this day, and the program given by both organizations was of such a nature that papers of interest to the whole attendance were presented.

At the afternoon session of the Illinois Clay Manufacturers Association meeting, a discussion of the forced draft system of burning was taken part in by C. E. Carter of the Peoria (Ill.) Brick and Tile Co., Harvey C. Adams of the Danville (Ill.) Brick and Tile Co., E. F. Plumb of the Streator (Ill.) Brick Co., and R. K. Hursh of the Department of Ceramic Engineering, University of Illinois.

Professor E. W. Washburn presented a talk on "Some of the Factors Involved in the Drying of Clay Wares."

Professor Carl B. Harrop, of the Ohio State University, and Conrad Dressler, of New York, gave a symposium on tunnel kilns, which proved of considerable interest to all those who attended.

"Belts and Bearings" was the title of a paper read by Professor G. H. Radebaugh, of the University of Illinois.

"The Composition of a Paving Brick as Related to Its Rattler Test" was the title of a paper read by Professor C. W. Parmelee, of the University of Illinois.

Following the dinner, at which forty-eight men were in attendance, a program was conducted under the auspices of the Chicago Section of the American Ceramic Society. Mr. H. P. Matzen, of the Carrier Engineering Corporation of Chicago, read a paper on "Humidity Drying." Mr. I. E. Hardy, of the Tiffany Enamel Brick Company, Mokena, Ill., addressed the guests on the subject of "The Enamel Brick Industry." Mr. W. E. Gates, Professor C. W. Parmelee, and others also spoke on timely subjects.

Meeting of the Northern Ohio Section

The eighth meeting of the Section was held in Detroit, Mich., April 5th, with the members present assembled at Hotel Statler. In spite of the inclement weather prevailing at the time, about thirty members gathered for a day of inspection trips arranged by the local committee.

The plants of the Jeffery-Dewitt Co., The Detroit Star Grinding Wheel Co., The Pewabic Pottery and the Ford Automobile Co. were visited. At noon lunch was served at the Detroit Athletic Club, as we were guests of the Jeffery-Dewitt Co. After lunch a short business session was held. Dinner was held at the Detroit Athletic Club, and those who wished went to theatres later.

A vote of thanks was extended by the Section to Mr. Riddle and associates of the program committee and to the officers and research staff of the Jeffery-Dewitt Co. for their hospitality and effort in making the meeting so successfull.

CHARLES H. STONE, JR.,
Secretary-Treasurer.

Important Actions of the Board of Trustees

March 25th.—It was voted that no membership list of the Society as a whole, or of any Industrial Division, shall be published or distributed except in the Year Book of the Society, or as otherwise ordered by the Board of Trustees, and that it shall be the duty of the officers of Divisions and of the Society to refer inquiries for lists of members to the chairman of the Committee on Publications, who is in charge of the selling of advertising space in the JOURNAL.

JOURNAL OF THE AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 3

June, 1920

No. 6

EDITORIALS

PURE *versus* APPLIED SCIENCE

There has been some discussion here and there as to the relative value of the contributions toward the advancement of ceramic knowledge made by scientists and technical ceramists. It has been claimed that the former class has contributed more substantially than the latter and that, hence, scientific research, *per se*, is the predominating factor. Furthermore, it has become in vogue among chemists to accuse the ceramic industries of being backward and unscientific.

Such discussions are in the nature of the case of doubtful value since they raise the old question of pure *versus* applied science. It is obvious that we must first have pure science in order to apply it. The question, therefore, reduces itself to the issue whether the technical work of the ceramic industries would be better directed by men trained solely in the sciences than by those combining a certain amount of scientific training with specialized instruction in ceramic technology. This evidently neglects the very important factor that those having a leaning towards general scientific research usually have no desire to engage in industrial work.

Since the subject of ceramics, in the nature of the case, stands for the application of the several sciences to industry, the criterion of success must be the tangible results represented by decreased cost of production, fuel economy, the evolution of new products and processes, the control of manufacturing operations, etc. Considered from this standpoint, the investigators of pure science

can not make a convincing or even creditable showing. Magnificent porcelain has been made for many decades without a knowledge of its micro-structure; excellent silica brick have been produced for many years without a knowledge of the silica inversions; glasses of many varieties have been manufactured successfully for a long time; portland cement of good quality has been made for almost a century by methods based only on simple chemical procedure; the continuous and tunnel kilns owe nothing to the scientific investigator. These and many other accomplishments have been brought about through empirical procedure and experimentation, governed by the same inexorable laws of cause and effect as strictly scientific investigation. Far be it from us to decry scientific work or to deny the necessity of lending it our full support; but the two fields, pure and applied science, are distinct and separate. To consider, for instance, the subject of ceramics to be a branch of physical chemistry is erroneous, to say the least. The physical chemist deals with general problems and methods pertaining to pure science, irrespective of any industrial application. It is the function of the ceramist to acquaint himself with the principles of those sciences having a direct bearing upon his field *and in addition* to master the treatment of materials, furnaces and kilns, which constitute the basic part of manufacture. Furthermore, he must be familiar with the history, development and economic status of his industries. A physical chemist, no matter how accomplished he may be in his science, has not mastered the subject of ceramics unless he possesses all of these qualifications.

Scientific work in the physics, chemistry and mineralogy of ceramic materials is most desirable. But it is the specific task of the physicist, chemist and mineralogist.

It is true, however, that the general scientific training offered in ceramics is not always adequate and that the teaching of ceramic subjects may be weak, merely descriptive and lacking in that happy combination of sound theoretical and practical presentation which is so essential. There is no reason why the scientific principles underlying ceramic technology should not be incorporated in the technical studies in a logical and exact manner. That there is considerable room for better teaching in

ceramic schools is shown in the contributions by recent graduates in the JOURNAL and by the experience of research laboratories employing such assistance. There is need not only of better undergraduate teaching but also of opportunities for post-graduate study either in colleges or in research laboratories.

Technical men, properly trained in ceramics or ceramic engineering, are able to render maximum service to the industry and can maintain our literature on a level with that of modern chemical, metallurgical and mining engineering. Those who desire us to direct our activities into the channel of one science have a narrow and misleading conception of the field of ceramics, which is not a branch of chemistry any more than is mining engineering.

ORIGINAL PAPERS AND DISCUSSIONS

DESIGN FOR A FIRE BRICK PLANT¹

By R. H. MINTON

In designing a clay-working plant of any kind today three important considerations are involved.

First: To make it as nearly automatic as possible, thus reducing the amount of labor involved.

Second: To arrange the processes and routing as efficiently as possible, to make the housing compact in order to keep down the capital investment.

Third: To equip the plant with the most efficient drying and burning system possible.

In the plant shown here an attempt has been made to carry into execution these three points as far as seems possible. It is designed to use the dry-press process for plastic fire clays.²

Clay Storage.—The clay storage room extends full width of, and adjacent to, the manufacturing room. This storage room has two overhead tracks upon which the clays are delivered by gravity from the clay banks. An overhead electric crane operating all over the room is so arranged that a grab bucket, with automatic measuring device, will take clay from any pile in the proper proportion for the mix.

Preparation.—The mix is dumped by the crane into a hopper which feeds a wet pan. By this process all the different clays are thoroughly mixed in order to give a much greater uniformity than if the clays and grog were run through a dry pan only. Tests

¹ Received February 27, 1920.

² Plant of S. G. Brinkman, Fords, N. J., operating partly according to this general scheme.

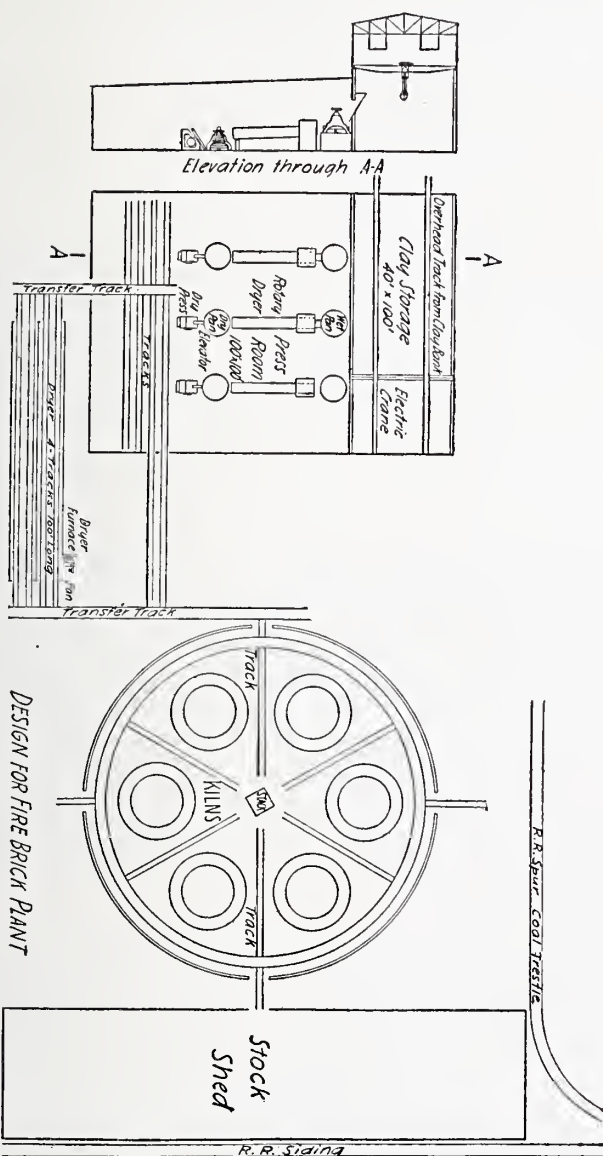


FIG. 1.

have shown that where the various clays are thoroughly blended a superior product results.

These wet pans are designed with a stationary rim which does not turn with the pan as in the ordinary type. This rim has a portion hinged like a gate, and an automatic device causes this gate to swing inward after so many revolutions of the pan, and causes the pan to empty itself into the rotary dryer.

Rotary Dryer.—In the usual stiff-mud or soft-mud method of brick manufacture the brick are made in the plastic state and the water driven off in the dryer. By the dry-press process the wet mix is first run through the rotary dryer and the excess water driven off. The mixture is not dried to any great extent but only sufficiently to allow running through the dry pan. The mixture comes in a continuous stream from the dryer into the dry pan from which it is conveyed by an elevator to the hopper feeding the dry press. No screen is used.

Dry Press.—The dry presses have their molds equipped with electrical heating units, which eliminate the usual steam connections. These presses are also equipped with an automatic mold-filling device which permits the handling of a clay mixture with, as much as 17 per cent of moisture. By the usual dry press process the moisture content is limited to about 10 per cent, and the physical bond of the brick is rather weak. The strength of the burned brick depends upon a bonding clay, which, of course, lowers its melting point. By this process it is possible to dry-press brick having almost as much moisture as by the stiff-mud process. The resultant brick has the physical strength of those made by the stiff-mud process.

Dryer.—The pressed brick are run through a dryer to dry them sufficiently for setting. The driers are equipped with a fan connected with a waste-heat pipe extending from the tops of the kilns. Hot air for drying may be had from all burning and cooling kilns. When there is not sufficient waste heat direct heat may be had from a coal-fired furnace connected to the fan.

Kiln Room.—This plant is laid out as a unit with six kilns holding 32,000 brick each. These kilns are built in a circle around

a central stack to which all are connected. The kilns are housed in a circular building, which may be of brick with a brick crown for the roof, or it may be a steel structure. Around the circle of kilns is a transfer track with exits at the four quarters of the building. There is also another circular transfer track within the

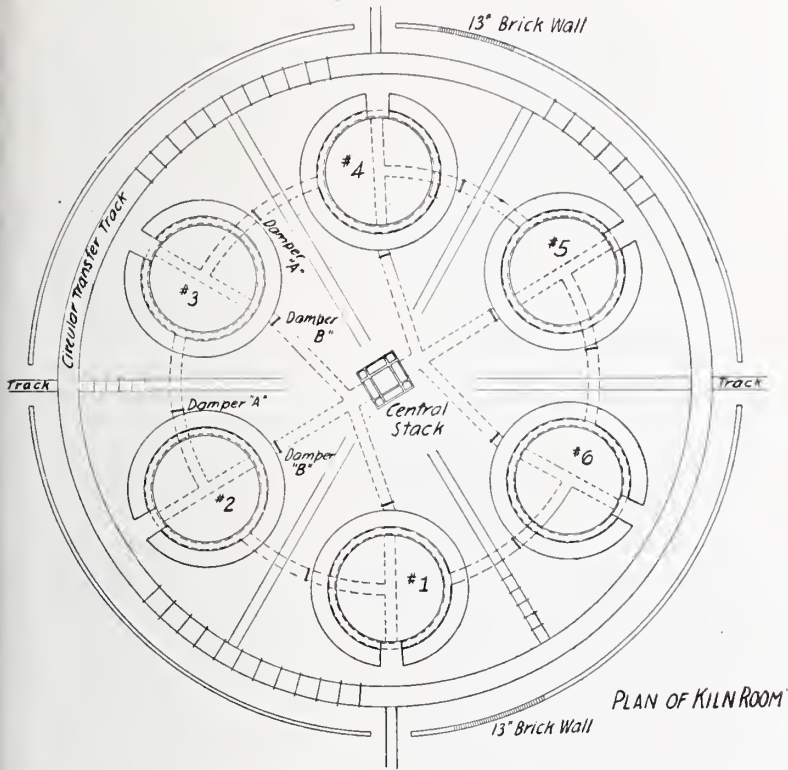


FIG. 2.

circle of kilns. This makes the coaling of the kilns quite convenient.

Firing Process.—Each kiln has a circular flue extending around it under the wall and below the fire-box ash pits. This circular flue is connected by a flue leading from the main cross flue of the preceding kiln. When firing a kiln it is possible to lead the draft directly to the stack, or by use of dampers to lead the hot gases

through one or more kilns in advance which may be ready for firing. Thus by closing damper "B" of kiln 2 and damper "A" of kiln 3 and opening damper "A" of 2 and damper "B" of 3, it is possible to utilize the hot gases from kiln 2 to watersmoke kiln 3.

Construction of Stack.—Only one stack is used for all six kilns. It is constructed in such a manner that there is an air space between the inner stack and the outer stack. This construction does away with the usual cracking of kiln stacks due to over-heating.

Construction of Kiln.—The kilns are of the downdraft type. There is a main cross-flue leading from wall to wall. Beneath this cross-flue is another flue leading from the center of the kiln to the stack. At right angles across the main cross-flue are jet flues supporting the floor blocks.

A circular flue extends around the kiln just under the wall and below the ash pits. This flue is connected by smaller flues leading into the sides of each ash pit. By this system the hot gases from a preceding kiln on fire may be led into the ash pits and through the grates into the kiln.

Fire Boxes.—One of the most important questions today for every clay man is the question of how to save fuel. Shall he use coal, producer gas or oil? Shall he install tunnel kilns at great expense? Unfortunately many manufacturers are unable, either from conditions or on account of the expense, to discard their periodic kilns and install the now efficient tunnel kilns. The problem, then, is to make the most of what they have by changing their kilns to the most efficient construction possible.

The fire box in this type of kiln is made with two sets of grates. The upper inclined grates hold the freshly supplied coal and act as a coking plate. The gas of the coal is driven off here and burns in passing over the white hot coal bed on the lower grates. It was found necessary to reconstruct this fire box some twenty times before the right proportions were obtained. In practice it is found necessary to allow a free air passage over the coal on the inclined grates. This construction seem to act as a small gas producer,

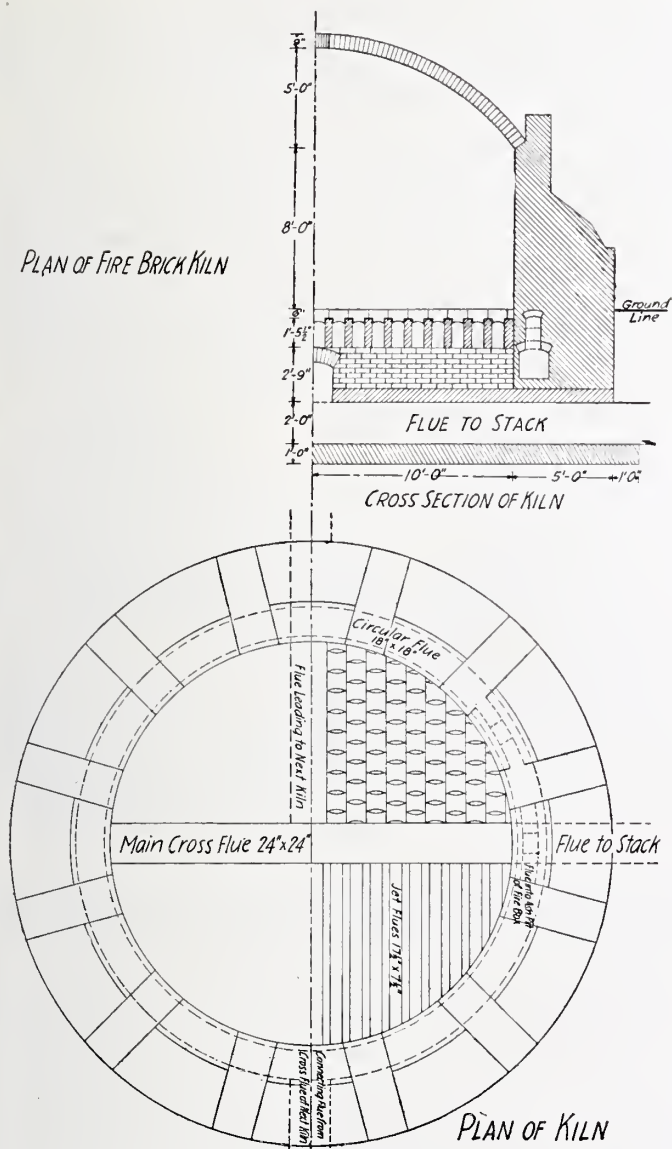


FIG. 3.

and the control is such that the combustion can be made to take place in the kiln, and not part of it in the stack or open air. Even when a kiln is on full heat and directly connected to the stack no smoke ever appears.

Economy of Kilns.—These kilns holding 32,000 to 33,000 nine-inch brick, have been fired to cone 15 in four days with fifteen tons of coal. A tunnel-kiln builder states that the yearly average consumption of coal for production of five million fire brick fired in downdraft kilns was 1440 pounds per thousand, and

*Fire Box Construction
Down Draft Fire Brick Kiln*

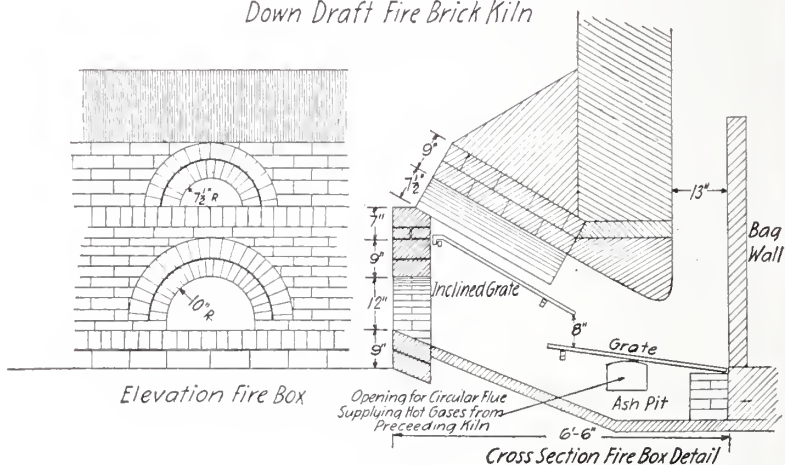


FIG. 4.

for the tunnel kiln the average was 650 pounds per thousand. With this type of kiln the average has run around 900 pounds per thousand brick.

Forced Draft in Kilns.—The question of forced draft in firing ceramic kilns deserves much more consideration than it seems to have received. We are all familiar with the evolution of locomotive boilers. The old type engine had a large, awkward stack, which has gradually been reduced by use of forced draft until the immense locomotives have little more than an opening for the escape of smoke.

With this type of kiln construction it is feasible to attach a blower to the flue leading from one kiln to the next and use forced draft under the fire grates. Burning by forced draft overcomes the variation of natural draft through weather changes and would also tend to more uniform results. With ordinary natural draft there are many currents in a kiln and the temperature is not uniform. By maintaining a pressure of an ounce, or so, in the kiln the temperature is forced into all parts, and the kiln is uniform throughout.

Dryer Construction.—The method of constructing the dryer roof is somewhat unique. It is formed with straight hollow build-

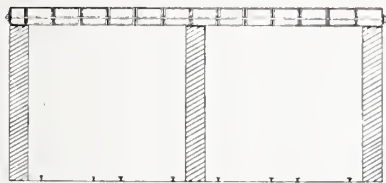


FIG. 5.—Cross section of tunnel dryer, showing tie-rod arch construction.

ing blocks 12 by 12 by 8 inches, with the hollows running across the width of the dryer. Through each course of tile is run an iron rod, slightly below the middle of the tile. This rod passes through plates on the outside of the tile course, and is drawn up by nuts so that it is under tension. This forms a rigid construction, capable of carrying any load, if necessary, at a low cost.

Conclusion.—A plant according to this design should be able to operate with a low labor element on account of the semi-automatic machinery equipment and the simple method of manufacture. Because of the efficiency of the kilns the important item of burning cost should be as low as is possible with the use of periodic kilns.

GENERAL CERAMICS CO.
METUCHEN, N. J.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

A POSSIBLE EXPLANATION OF FAILURE UNDER LOAD AT HIGH TEMPERATURE AS DISPLAYED BY FIRE CLAY REFRACTORIES¹

BY ARTHUR S. WATTS

The following is not offered as conclusive evidence but rather as a peculiar combination of facts which have come to my attention over a period of years and which appear all to point in one direction.

The general impression prevails that all clay refractories fail under load when a temperature of about 1300° C. is reached. This has come as a result of the work of Hereaus,² Bleininger and Brown,³ and others who have carried on tests with European fire clays and American fire brick. Bleininger and Brown, page 67, in the article just cited, decide that failure at 1300° C. under a 75 pound per square inch load will result from a total flux content of 0.225 molecular equivalent or more, regardless of the content of silica but calculating the alumina as 1. The failure is pointed out as being due chiefly to an inferior bond clay and that the inferiority of the bond clay is oftener due to high flux content than to high silica content. The development of easily fusible silicates at low temperatures and the progressive solution of additional silica and alumina with increased temperature or with a prolonged exposure to the same temperature is presented as sufficient cause for the failure of the refractory under load.

The foregoing is undoubtedly the cause of some premature failures under the conditions specified; but it has become apparent to every user of fire-clay brick that the brick begins to weaken mechanically under load at a temperature below 1300° C. regardless of how low the alkali content or how nearly the $\text{Al}_2\text{O}_3\text{-SiO}_2$ formula approaches that of pure kaolinite.

¹ Received Feb. 27, 1920.

² *Zeitschrift f. angew. Chem.*, **18**, 49 (1905).

³ U. S. Bur. of Standards *Tech. Paper*, 7.

Bleining and Brown¹ show a brick containing 0.81 per cent total alkali, 39.19 per cent Al_2O_3 and 56.62 per cent SiO_2 , which begins to deform under load at 1291°C ., although its actual fusion temperature is given as cone 31 $\frac{1}{2}$ (approximately 1695°C .). Another brick with 0.88 per cent total alkali, 40.42 per cent Al_2O_3 and 54.51 per cent SiO_2 begins to deform under load at 1207°C ., although its actual fusion temperature is given as cone 31 (approximately 1685°C .). Another brick having 0.92 per cent total alkali, 43.41 per cent Al_2O_3 and 52.89 per cent SiO_2 begins to deform under load at 1213°C ., although its actual fusion temperature is given as cone 31 (approximately 1685°C .). On the other hand, these writers show a brick containing 0.66 per cent total alkali, 19.00 per cent Al_2O_3 and 77.82 per cent SiO_2 , which although its actual fusion temperature is given as cone 29 (approximately 1650°C .), *i. e.*, lower than of the preceding three, shows no tendency to deform under the load test. Of the four refractories cited, all contain less than one per cent flux. Three have Al_2O_3 and SiO_2 contents approaching the kaolinite formula and all these fail under the load test. The fourth has a low Al_2O_3 and high SiO_2 content, and stands the load test. The difference in flux is not sufficient to cause the difference in behavior and it can, therefore, only be due to either the low Al_2O_3 or high SiO_2 .

Bleining and Brown also state² "a clay fairly high in fluxes, corresponding, for instance, to 0.22 RO- Al_2O_3 2 SiO_2 would be improved by the dilution with silicious material containing practically no fluxes, or even by the addition of a clean sandstone, the principal requirement being intimate blending and grinding." The advantage of reducing the flux content by adding pure SiO_2 is thus acknowledged, but no note is made of the effect of reduction in Al_2O_3 content.

The writers also make an important observation on page 62 where they observe "The hardness of burning in general is a factor worthy of consideration. Our work has shown that well-burned bricks stand up better than soft-burnt products." On page 73 "Experiments carried on by the writers have shown that

¹ U. S. Bur. of Standards *Tech. Paper* 7, pp. 52 and 56.

² *Tech. Paper* 7, p. 71.

harder burning has increased the strength of fire brick appreciably. The superiority of high-fired over low-fired ware from every standpoint, especially as regards change in volume when part of the furnace wall, is so striking that every effort should be made to push the maximum possible burning temperature." The hard burning is justified by the fact that the more fusible bond clays absorb some refractory flint clay and are thus improved as regards resistance to load.

A study of all the data above mentioned, has raised the inquiry in my mind, whether this weakness displayed by high alumina clay refractories is really due to the progress of pyrochemical solution or whether it can not be more properly charged to a period of physical weakness produced in the mass by the decomposition of the kaolin and the recombination of the Al_2O_3 and SiO_2 as sillimanite.

If such a change can be shown to occur at about the temperature where failure is observed this would be a logical explanation and in line with observations in other similar cases. For example, we recognize the crystallization in masses of metal as a direct cause of mechanical weakness. Also we recognize the change of crystal form in silica as an explanation of failure in this class of refractory. Why then should not the development of sillimanite be considered as the cause of failure in clay masses in which it is known to exist.

As regards the temperature of development of sillimanite there can be no doubt but that it does mature as low as 1170°C . when the mass is only commercially vitreous. This fact I proved in an investigation of paving brick a few years ago, and I presume abundant additional evidence could be obtained to justify this temperature as within the limits of sillimanite development. The temperatures at which Bleining and Brown observed deformation were with but three exceptions above this temperature.

Furthermore, vitrification is not necessary to the development of sillimanite which has been shown by Glasenapp and others to be not a case of crystallization out of solution but a case of molecular rearrangement by which, as Glasenapp states, "All clays become crystalline at high temperature coincident with the de-

composition of the clay substance." If then the development of sillimanite is merely the product of molecular rearrangement without fusion, the mechanical failure of the mass due to this molecular change would begin as soon as sufficient temperature for such change was reached.

However, since the publication of the above statement of Glasenapp, some other evidence has developed which has a distinct bearing on the case. Zoellner conducted an investigation at cone 15 to ascertain whether all clays would produce an equal yield of sillimanite provided they contained the same Al_2O_3 content. The results of his investigation are given in the following table:

| | SiO_2 | Al_2O_3 | Fe_2O_3 | CaO | MgO | KNaO | H_2O | Sillimanite residue |
|----------------------|----------------|-------------------------|-------------------------|--------------|--------------|---------------|----------------------|---------------------|
| Zettlitz kaolin..... | 45.66 | 38.54 | 0.90 | 0.08 | 0.38 | 0.66 | 13.00 | 20.5% |
| Kemnitz kaolin..... | 54.2 | 32.9 | .29 | .17 | .13 | .49 | 11.82 | 21.12 |
| Poschez kaolin..... | 45.6 | 39.23 | .80 | .20 | .22 | .83 | 13.42 | 22.4 |
| Wildstein clay..... | 47.7 | 35.7 | 2.2 | .25 | .10 | 3.02 | 11.2 | 2.1 |
| Putschirn clay..... | 56.0 | 30.0 | .. | Trace | .20 | 1.7 | 12.1 | 5.8 |

Thus we find three kaolins when fired at cone 15, yielding from 20 to 23 per cent sillimanite. Two ball clays, however, which have almost the same Al_2O_3 content as the kaolins but which vitrify at cone 15, yield less than 6 per cent sillimanite. Zoellner concludes that the earlier vitrification and the development of complex silicates made possible by the higher flux content is the cause of the very low sillimanite development in ball clays.

If sillimanite development is the cause of weakness in high aluminous clays around 1200°C . and if ball clays are notably free from such development, then refractories high in ball clays should display little weakness around this temperature. And this is exactly the fact which I wish to call to your attention. As the tendency to fire our white wares higher has called for more durable saggars and as the increased use of the sagger machine has demanded a plastic mass which would flow more freely than the old sagger mixes, we have resorted to the use of increasing amounts of ball clays of poor color but good refractory value. The admixture of even a moderate amount of fire clay has been found distinctly injurious even though its fusion temperature was equal or superior to that of the ball clay. The only other clay

found suitable for mixing was a highly silicious clay, as a wad clay or some such clay. A highly silicious kaolin in crude form, called "spar" is used in the east, and in Ohio a highly silicious but refractory flood plain clay is used. In both cases the saggars are far superior to anything that can be produced by the use of the best flint and plastic fire clays. The saggars containing fire clays are mechanically weak and crack after a few firings at best while the ball clay saggars if properly made seem to last almost indefinitely unless broken in handling. Limited study of fire clay saggars showing abnormal weakness apparently show high sillimanite development which is strikingly absent in saggars made from ball and wad clays, but further study and investigation is considered necessary before any positive statement can be made in the matter. If anyone has any contradictory evidence, the writer would be more than pleased to hear of and consider same.

DEPARTMENT OF CERAMIC ENGINEERING
OHIO STATE UNIVERSITY
COLUMBUS, OHIO

Discussion

MR. R. T. STULL: The development of weakness during the transition period, or period during change of state, is well recognized. A prominent metallurgist cited to me a very interesting illustration. In manufacturing a special grade of steel, a difficulty was encountered during the rolling process. About the middle of the rolling process the steel would crumble, due to a change in physical state.

The difficulty was obviated by giving the billets a preliminary rolling, then setting them aside for a few minutes until the change was completed, then finishing the rolling process.

The period during the dissociation in the fire brick preceding the formation of sillimanite represents a period of weakness in those brick which have been previously fired at temperatures below that at which sillimanite forms in appreciable quantities. But after the sillimanite has been formed, the strength of the brick returns to a greater or less degree, which may explain the fact that brick burned to high temperatures withstand the load test better than soft-burned brick.

DR. E. S. MOORE: Speaking from the standpoint of the mineralogist and petrographer, it seems reasonable that the proportion of silica present should have a very marked influence on the relative amount of sillimanite formed. In the first place, an increase in silica tends to increase the viscosity, to retard molecular movement in the solution and to retard the development of the sillimanite, and in the second place the more silica present, the greater the tendency to form disilicates or meta-silicates instead of the orthosilicate, sillimanite. These conditions are illustrated in the development of minerals in rocks.

MR. M. C. BOOZE: It is not clear whether Prof. Watts attributes the failure of fire-clay refractories to sillimanite formed during the load test or during the initial firing. If he refers to the latter, then, according to theory advanced, higher firing with an accompanying increase in crystalline sillimanite should weaken the structure and give greater deformation in the load test. This is contrary to practical results.

But little sillimanite could be formed during the load test burn since the decomposition of the kaolinite molecules and the formation of sillimanite would certainly have gone far enough during the initial burn of several days' duration that but little more would be formed during a six-hour test burn. Certainly, in the case of those refractories which are fired for a long period and at a maximum temperature as high as that received during the load test, there would be practically no further development of sillimanite during the load test burn. Yet these refractories do fail in the load test and with other things constant their deformation is a function of the bond clay used. These bricks behave under load in a way quite typical of all fire-clay refractories. According to the explanation advanced by Prof. Watts we would expect a different behavior since the strains produced by sillimanite crystallization are absent. If failure were due to molecular decomposition of the clay and the formation of crystalline sillimanite, the failure should be comparatively sharp, such as obtained with a silica brick. The typical fire-clay refractory failure shows a gradual swelling of the base and a round-

ing of the sides which means that the viscosity of the bond has been lowered and the brick has flowed under pressure.

Mellor¹ has discussed the load test as applied to high alumina clays and states that with such refractories "there does not appear to be a limit to the decrease in refractoriness under an increasing load." This he explains as being due to the fact that the melting point of alumina is decreased by pressure and which will explain the abnormal deformation observed by Prof. Watts in high alumina refractories.

MR. A. A. KLEIN: Although the formation of sillimanite as a result of clay dissociation might possibly be the cause of introducing slight strain in fire-clay bodies it is absolutely certain that this is of very little if any importance in the explanation of the failure of refractory clay bodies under load at high temperature. In the first place the conditions attending upon the formation of sillimanite are not as Prof. Watts points out analogous to crystallization in steel since there is always some liquid phase present at the temperature of sillimanite formation which tends to dissipate the strain.

Again his analogy to silica brick does not seem to be warranted. In the first place the formation of cristobalite and tridymite involves expansion due not to chemical reaction but to thermal inversion. This takes place not only in the fine groundmass of the silica brick where there is a little liquid phase present during the inversion but also in the coarse granules (phenocrysts) where the inversion proceeds inside the crystals in the absence of any flux due to impurities.

This effect is quite contrary to that noted by Bleining and Brown (B. of S. Tech. Paper No. 7) on fire-clay bricks which had failed in the load test. On page 57 they state that "inspection of the failures shows plainly that the more refractory flint fire clay has not softened to the slightest extent. The grains have lost none of their original identity. They seemed to have slid upon each other, the bond clay behaving analogously to a lubricant. From this it follows that no matter how excellent the major con-

¹ *Trans. Amer. Ceram. Soc.*, **17**, p. 94.

stituent of the brick may be as to refractoriness, if the bond clay is too deficient in this respect the load carrying power of the product is impaired."

A close examination of the compositions cited by Prof. Watts (Tech. Paper No. 7, pp. 52 and 56) with particular reference to figure 28 where the behavior of all samples under load test are recorded shows that an apparent little difference in RO content may be of importance in causing failures. For instance composition 30 failed and 23 did not fail. Their compositions were as follows: Molecular equivalents of RO equals 0.175 and 0.15 respectively; molecular equivalents SiO_2 : Al_2O_3 equals 3.6 and 3.7 respectively.

Furthermore in that portion of the field as given in figure 27 where failures were predominant they were not universal. Such a condition would be impossible to explain on the basis of sillimanite inversion as indicated below.

The temperature of sillimanite formation and the growth as well as the development of sillimanite crystals depend mainly upon the composition of the body. The relation of its formation to the temperature of burning as given in Bur. of Stand. Tech. Paper No. 80 on the constitution and microstructure of porcelain, table 4, holds only for compositions used in porcelain practice.

The data are quite different for products of low flux contents (fire-clay refractories), and the formation of sillimanite here takes place with more difficulty and at higher temperature than in bodies of porcelain composition.

Furthermore, recently we have found the development of large, well-formed sillimanite crystals resulting from kaolin dissociation at 1000°C . in the presence of a very low fusing reactive flux. This is apparently not in accord with the work of Zoellner but is based upon our experience in the microscopy of bodies containing kaolin. Zoellner's sillimanite results which depended upon differential chemical reaction are open to the same question of accuracy as the values obtained by the rational analyses of clay.

Aside from this the inspection of Zoellner's analyses as given by Watts shows that the Wuldstein and Putschvin clays contain

more alkali than the kaolins. Figuring the alkali to the formulas of feldspar or mica, it is certain that the actual amounts of kaolinite ($\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$) present in these clays were by no means constant. It follows also that the actual amounts sillimanite produced by dissociation of the kaolinite should not have been constant.

It is our experience that products of the same composition should show substantially the same sillimanite formation under the same thermal conditions; and if this is the cause of failure, they should all fail together, which is certainly not so as shown in Tech. Paper 7, figure 28.

It follows also from Prof. Watts' theory that fire-clay brick which have greater sillimanite development, and for a definite composition this could only be brought about by greater heat treatment in burning, should show greater tendency toward failure. This is contrary to universal experience since it is well known and has been pointed out by Bleining and Brown as well as by others, that higher burning produces harder brick which tend to give better results under the load test.

The present data indicate that in general failures under load are due to the undue fluxing of the bond clay and that the tendency toward failure can be reduced by finer grinding and blending as well as by harder burning.

MR. WATTS: Replying to the discussion of Mr. Booze, I would explain that the sillimanite must have formed during the original firing, if that firing reached the temperature of the test. However, any additional burning at that temperature or above would undoubtedly add to the sillimanite development. The proportion of sillimanite which would form during any given period is recognized as dependent upon the time and temperature employed. The cause of weakness, however, is not the sillimanite crystallization but the period of weakness caused by molecular rearrangement due to sillimanite development. The sillimanite itself, if its crystallization was sufficiently coarse to form a matrix, would theoretically add strength to a mass; and this is doubtless the case where the material is burned well beyond the

temperature at which the sillimanite forms prior to the application of the load test. Where, however, the development of sillimanite occurs at the time of the application of load, the molecular rearrangement due to its formation must cause a more or less distinct period of weakness; if the development of sillimanite is abrupt, the weakening of the mass would be abrupt, but if the sillimanite development was gradual the weakening would be gradual, which is what we observed.

Regarding the statement by Dr. Mellor, quoted by Mr. Booze, I believe that the interpretation is misleading and that Dr. Mellor intended to convey the impression that the melting point of alumina would be decreased by pressure equally applied from all directions as a physical state and not that a load placed upon the mass of alumina from one side only would lower its melting temperature.

Mr. Klein's point that the conditions attending the formation of sillimanite are not analogous to the crystallization phenomena in steel is not clear to me. The period of crystallization in steel is distinct, and any pressure applied within the temperatures of this crystallization would cause a tendency to rupture. It is reasonable to believe that if a mass of aluminum silicate undergoes a change from the amorphous to the crystalline state or that a complete molecular rearrangement occurs, such a period must necessarily be one of temporary weakness. Mr. Klein says that some liquid phase is always present at the temperature of sillimanite formation. I should like to see proof offered that this is the case when a mass of pure kaolin is heated to a temperature of cone 15, approximately 1430°C , and sillimanite develops in considerable quantity. So far as my observations have gone the change is not attended in such cases by the development of sufficient liquid phase to function as a lubricant to the crystalline particles formed. The analogy to silica brick was merely, insofar as a period of weakness exists, due to a change of physical state. In this sense I cannot understand why Mr. Klein does not see the similarity. It is not the intention of the writer to offer the theory presented in this paper as a substitute for the explanation presented by Bleining and Brown, and he thoroughly

understands and appreciates that in a great majority of cases their explanation is the only plausible one; but in the paper presented he merely suggests that evidence points, in his judgment, to the fact that a distinct period of weakness exists in masses of aluminium silicate when they are undergoing a molecular rearrangement, due to the development of sillimanite.

The statements regarding the formation of sillimanite as regards temperature are so well understood and agreed upon that I cannot understand why Mr. Klein takes space to repeat them. I would call attention to the fact, however, that Mr. Klein is apparently more concerned with the size of the crystal than with its existence as a new constituent of the mass. The crystallization may even be sub-microscopic, and yet the period of molecular rearrangement could be expected to constitute a period of weakness in the mass. As regards the development of large crystals of sillimanite I would say that these have been for the last fifteen years produced by the intimate mixing of kaolin and some easily fusible mineral, such as boric acid. These crystals, however, are rarely encountered in refractory masses and do not concern this discussion. Their development, however, was explained by Zoellner contrary to Mr. Klein's statement. Zoellner's sillimanite data did not depend upon differential chemical reaction, as Mr. Klein states, but upon microscopic identification and chemical analysis of the crystalline material produced.

Regarding the Wildestein and Putschern clays containing more alkali, I would call your attention to the fact that Mr. Klein attempts to explain coarse sillimanite crystallization by the presence of low fusing reactive flux. The presence of an excess of alkali, which is apparently operative in the development of large crystals of sillimanite in porcelain, when fired at a proper temperature, does not yield sillimanite crystallization in these clays and in other plastic clays, so far as the writer's observation has gone. The behavior in clays is, therefore, apparently not analogous to the behavior in porcelains and Mr. Klein's data, based on studying porcelain mixtures, therefore, does not justify any general assumptions.

The most common cause of failure of clay refractories is undoubtedly the fluxing of bond clay and the finer grinding of the

bond clay would merely cause its more rapid fusion. The introduction of more refractory clay will undoubtedly reduce the distortion proportionately. The fact that such fusion does occur in a majority of cases is, however, in the writer's judgment not sufficient justification for disclaiming that the period of weakness created by the molecular rearrangement of the alumina and silica in the mass is not a factor worthy of consideration.

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NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

DATA ON THE OPERATION OF THE DRESSLER TUNNEL KILN IN THE MANUFACTURE OF SEMI-PORCELAIN DINNER WARE¹

BY IRA E. SPROAT AND DONALD ALLBRIGHT

Introduction

The data given in this paper have been obtained from tests and observations on the Dressler tunnel kiln at the Limoges China Co., Sebring, Ohio, during the nine-months period from April 1919, to December 1919.

The general principles of operation of this type of kiln are well known as they have been discussed several times before this Society. However, during about a year's travel over the rocky road of experience we have encountered a number of operating details which will probably be of interest to those who are manufacturing semi-porcelain dinner ware and are contemplating the installation of this type of kiln.

The Gas Producer

Quality of Gas.—One of the chief factors, if not the principal one, to be considered in the successful operation of the Dressler tunnel kiln is the quality of the gas and its proper control. Cool gas is desirable in the tunnel kiln, since such gas is more free from soot which, unless properly controlled, fills up the ducts, valves and burners. If carbon is allowed to accumulate in the burners, it may be the source of much trouble and consequently interfere with the proper regulation of the temperature within the kiln. It is not always possible to obtain the quality of gas desired; therefore, to offset any trouble from this source the burners should be cleaned regularly and frequently. This will prevent the accumulation of a sufficient amount of carbon to cause any trouble by cracking a burner.

¹ Received February 27, 1920.

Another feature to be considered in this connection is the distance between the producer and kiln proper. If the producer is at least 20 feet from the kiln, the major portion of the carbon in the gas will be deposited in the duct leading to the kiln where it is very easily and readily removed by the simple expedient of burning it out with kerosene.

A cool gas may be described as one graduating from a straw color to a blue, depending upon the amount of volatile matter thrown off by the coal used. A brown or black gas is a guide to bad conditions inside the producer, and when this appears the fuel bed should be raked thoroughly with some deep poking to determine the cause, which may be either too hot a fuel bed, or blow-holes or both.

In a properly operated producer, the fuel bed is always visible through the poke holes. If the gas becomes hot, a conical-shaped short flame becomes immediately visible when the poke holes are opened. Usually, this condition is the result of one of two causes.

First: Blow-holes in the fuel bed through which the steam and air pass without decomposition. Thorough combination of these with the volatile materials driven off from the coal is the normal condition when the steam and air pass through the fuel bed in such a way as to come in intimate contact with the glowing coals. When a blow-hole occurs the sides of the "channel," as it is also called, become very hot, and the gas is burned within the producer to a considerable extent. To remedy this, rake the fuel bed, increase the amount of coal, and increase the proportion of steam to air at the blower.

Second: The flowing of too great a proportion of air to steam into the producer. To cool the fuel bed proceed as in the first case, namely, rake the fuel bed, increase the amount of coal and steam.

Therefore, it can be readily seen that the quality of the gas depends largely upon the skill of the operator. Too much stress cannot be put upon the advisability of uniform firing conditions. If a coal of comparative uniform composition is used and is fired in small quantities at regular intervals and the fuel bed raked at stated periods, it will be found that very few changes will have to be made in the gas and air inlets when once properly adjusted.

The changes necessary to produce the quality of gas desired can be made by an occasional change in the amount of coal added to the producer.

Standard Conditions of Operation.—We have found that three shovels full of coal, weighing 23 pounds each, fired into the

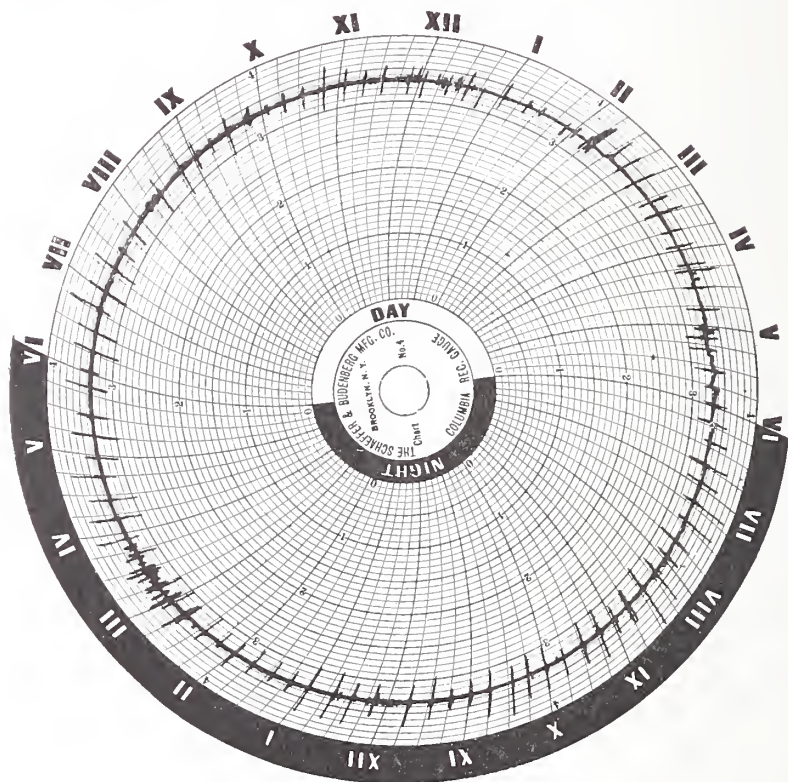


FIG. 1.

producer every 15 minutes produces sufficient volume of gas to properly operate the kiln, and that raking the fuel bed every two hours will generally be sufficient to avoid blow-holes and to distribute the fresh coal evenly over the entire fuel bed. Perhaps a still better way to rake the fuel bed is to rake through every other poke hole every hour. If these simple rules are adhered to

with precision, very little trouble, if any, will be experienced in the operation of the producer and the resulting bad effects on the uniform temperature within the kiln avoided.

The gas pressure is normally kept at 0.3 inch head of water, but this can be varied according to the requirements, such as burner openings, volume of gas consumed, etc. The chart (figure 1) is a typical pressuregraph record for 24 hours. The instrument has been set so as to be at zero pressure when the recording pen is at 3.0 on the chart. This was done so as to give more recording space and a correspondingly better and more complete record. Besides giving a record of the gas pressure this pressuregraph chart is a very good check on the time when the producer man adds more fuel to the producer, for every time the bell hopper is raised to admit a new charge of fuel the pressure drops, which is automatically recorded. These drops in pressure can be plainly seen on the chart.

The steam pressure is generally held at about 50 pounds.

Coal.—The best type of coal to use is one with a high gas content, and a low percentage of ash which has a comparatively high fusion point. The following is a typical analysis of a coal we have found to give good results.

| | |
|---------------------------|--------|
| Volatile combustible..... | 15.88% |
| Fixed carbon..... | 74.29 |
| Moisture..... | 2.12 |
| Ash..... | 7.71 |

B. T. U. per pound of coal, 14,150.

The Kiln

Since the results of changes in the position of the various dampers, inlets, and outlets of both air and gas supply, together with their many combinations, are far too many to be discussed in detail, as such a discussion would only tend to confuse the reader, the writers will confine themselves to a general description of the most fundamental principles of operation. Furthermore, we wish to emphasize the fact that any rule or principle of operation discussed in this paper can be treated in a very general way

only, and its proper application to a successful operation of the Dressler tunnel kiln depends largely upon the skill of the operator.

Balanced Gas and Air Supply.—One of the first things to be considered is the proportion of air to gas entering the combustion chamber. It can be readily seen that if more air is drawn through the chambers than is necessary to completely burn the gas at such a point, or points, where maximum temperature is desired, there is needless extraction of heat from the kiln. On the other hand, if too little air is admitted, combustion is incomplete and the amount of heat evolved greatly reduced. Therefore, in the manipulation of the air inlet and gas dampers to burners it is advisable to keep the following rule in mind:

“The greater the proportion of hot air to gas, the shorter the flame and the more intense the combustion, and conversely the smaller the proportion of hot air to gas the longer the flame and the less intense the combustion.”

However, it must be remembered also that the successful application of the above rule depends largely upon the foresight and skill of the man in charge, for there are very distinct limitations to the length to which it can be carried. For instance, the volume of air can be increased to a point where the heat in the crown of the kiln can be withdrawn more rapidly than it can be generated, due to the fact that the velocity of the hot air in the chambers is too great and the heat is not given sufficient time to penetrate the chamber walls at the hot zone but travels on farther down the chamber. Such a condition is similar to the results of too small a volume of air to gas, which lengthens the flame and raises the temperature toward the mouth of the kiln.

Factors Affecting the Quality of the Ware

This brings us to the consideration of the factors directly affecting the quality of the ware and the application of the above general principles in obtaining the desired results. In order to facilitate the study and to produce a clearer and more concise digest of the subject, we have divided the kiln into three arbitrary zones, namely, the heating up, soaking, and the cooling zones.

The chart (figure 2) shows very clearly the three different zones, the location of the pyrometers, and the location of the cars within the kiln.

Zone 1.—The heating up zone extends from the mouth of the kiln to pyrometer 8, a distance of 164 feet. In the forward portion of this zone the moisture and organic matter is driven off while in the latter portion of the zone the ware is partially matured.

The chief and practically the only trouble that can occur in this zone is fire-cracking due to too rapid heating of the ware in the early stages. This rapid advance in temperature in the early stages is generally caused by too long a soaking zone which encroaches on the pre-heating zone. This can very readily be remedied by decreasing the volume of gas, and if this does not produce the desired results the draft can be increased until a short and intense flame is secured.

Zone 2.—The soaking zone extends from pyrometer 8 to 10 and is 15 feet long. It is in this zone that the ware is brought to full maturity, and therefore it is this zone that requires careful and consistent attention in order to produce uniform results.

The chief problem in this zone is to obtain sufficient penetration of the heat to the bottom of the cars with resulting uniformity in the porosity of the ware. There are several changes which can be made to increase the heat treatment of the ware on the bottom of the car. Perhaps the chief one is to decrease the temperature on the top of the car and at the same time increase the length of the soaking zone. This is nothing more or less than the application of the same principle that is used in obtaining a better heat distribution in periodic kilns, namely, a longer soaking of the ware at a lower temperature.

A longer soaking can be obtained also by the simple procedure of decreasing the rate at which the cars travel through the kiln. However, this decrease in rate is to some extent limited by the desired capacity of the kiln. This rate of advance of the cars has the greatest influence upon the degree of penetration of the heat towards the bottom of the car. Therefore, this is generally the first change to make, for increasing the length of the soaking

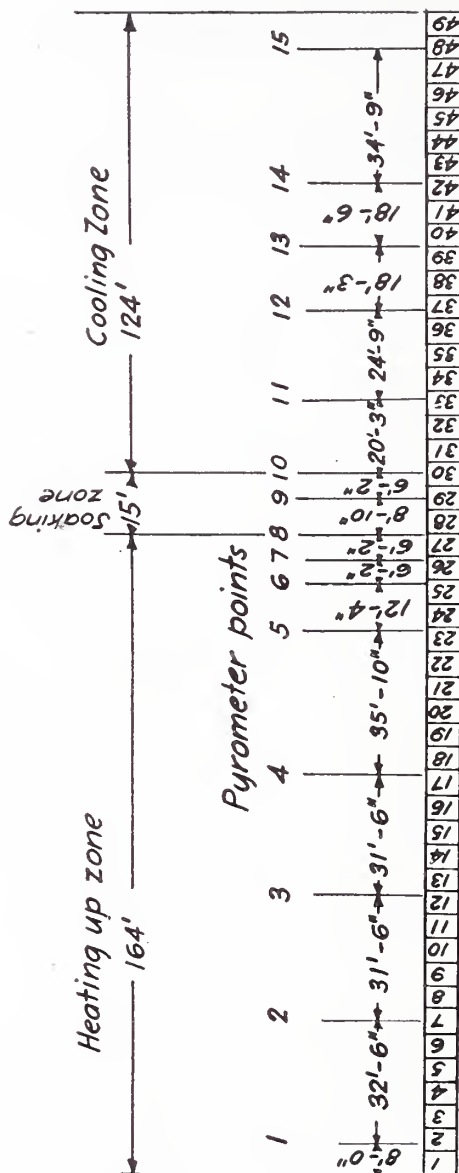


FIG. 2.—Diagram of kiln showing location of pyrometers and the relative position of the cars within the kiln.

zone is limited to a large degree by the distance the heat can be allowed to travel forward without causing too rapid heating of the ware.

Another factor which affects the degree of penetration is the manner in which the ware is placed on the cars, in saggars or in the open on shelves or racks superimposed one above the other. During the past nine months the ware has been placed in saggars in the usual way as is the custom in placing periodic kilns. The saggars are placed seven high on the cars, and each car contains on the average 60 common saggars. However, at the present



FIG. 3.

writing we have practically completed experiments with a saggerless car. These cars are simply a series of shelves six in number, six inches apart, superimposed one above the other, the supports being three-inch refractory tile. Figure 3 gives a good idea of these saggerless cars. The ware is placed on setters and then placed on the various shelves of the car.

Upon comparing the porosity of the biscuited ware from various sections of the saggerless car with tests of ware from the same section of the sagger cars directly in front and behind the saggerless car, we found that the kiln conditions which gave best results in a sagger car did not produce exactly, as uniform a product

in the saggerless car. The difference in the porosity of the ware from the top and bottom of the car was less in the case of the saggerless car; but on the other hand in nearly every instance the ware in the center of saggerless cars had a higher porosity than the ware on either side in the same horizontal plane. The porosity of the ware from the sagger cars in the same horizontal plane showed practically no variation.

Therefore, we see that under constant operating conditions the saggerless car does assist to some extent in obtaining a very even distribution of the heat between the top and bottom of the car; but when mixed cars are used this advantage is offset to some degree at least by the greater variation in the porosity of the ware from side to side of the car. This is evidently due to the fact that as the car passes into the cooling zone the saggars hold the maximum heat long enough to mature the ware on the inside. But this temporary fault of the saggerless car can easily be rectified, when all the cars entering the kiln are of this construction and the kiln has been regulated to meet the new conditions.

Probably the best feature which recommends the use of the saggerless car is the increased capacity obtainable. A sagger car on the average lists at \$175, while a saggerless car lists at \$325. As high as \$420 worth of ware has been placed on one of these saggerless cars.

Zone 3.—The cooling zone extends from pyrometer 10 to the exit of the kiln. The temperatures of this portion in the kiln are greatly influenced by the conditions farther forward, and, therefore, are less under the control of the operator. The main thing to be avoided in this zone is a sudden drop in temperature at any one point, because this will invariably cause a large percentage of dunted ware. A gradual and uniform drop in temperature is to be desired as dunts seem to be produced far more frequently when the ware has been subjected to a sudden change in the temperature during cooling. A comparatively rapid but uniform cooling is far better than a slow and changeable rate of cooling. Sudden cold drafts are sure to produce dunts.

Standard Conditions of Operation

The following standard conditions of operation are those we have found to produce the best results with the use of cars on which the ware is placed in saggers in the usual manner. At the present writing the conditions for saggerless cars have not been permanently determined.

Car Schedule.—Every one and one-half hours a car is put into the kiln and one taken out, making 16 cars of biscuit ware

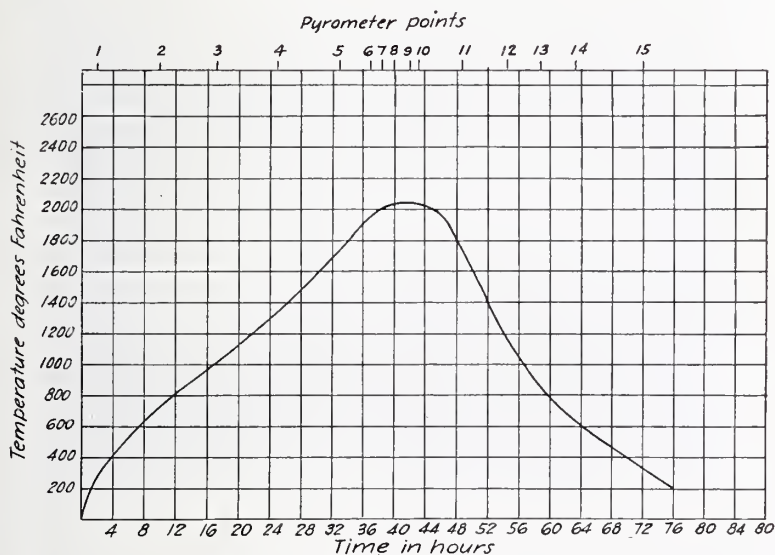


FIG. 4.—Model time-temperature curve.

every 24 hours with a combined list of approximately \$2800. Figuring a car length as 6 feet 2 inches the cars move at the rate of 4 feet $1\frac{1}{3}$ inches per hour. This was the minimum rate that we could use and still maintain our desired capacity with the use of sagger cars.

Time Temperature.—With the car schedule established at one and one-half hours, very satisfactory results have been obtained with temperatures at the various pyrometer points shown in figure 4. From a study of this curve it can be readily seen

that the ware is subjected to the maximum temperature for only $3\frac{1}{2}$ hours and the entire burn is completed in 72 hours. Owing to this short soaking period at the maximum temperature, cone 9 has to be down on top of the car in order to properly mature the body.

Draft.—We have found that a draft of 0.03 inch of water at the burner points give very satisfactory results.

The results recorded below are typical of those obtained under the above standard conditions during the past several months and are being duplicated week after week.

Temperatures in the Hot Zone.—Since the uniform porosity of the ware depends upon one's ability to maintain a comparatively constant temperature in the hot zone we record in table 1 the temperatures at pyrometers 8, 9 and 10 for an average 24 hours' run.

TABLE 1

| No. | Day | | | | | | |
|---------|-------|------|-------|-------|------|------|------|
| | 7.30 | 9.00 | 10.30 | 12.00 | 1.30 | 3.00 | 4.30 |
| 8..... | 2060 | 2070 | 2060 | 2070 | 2070 | 2075 | 2070 |
| 9..... | 2050 | 2050 | 2060 | 2070 | 2075 | 2070 | 2060 |
| 10..... | 2055 | 2060 | 2060 | 2060 | 2060 | 2070 | 2060 |
| | Night | | | | | | |
| | | | | | | | |
| 8..... | 2070 | 2080 | 2070 | 2080 | 2075 | 2070 | 2060 |
| 9..... | 2070 | 2070 | 2070 | 2070 | 2075 | 2070 | 2950 |
| 10..... | 2060 | 2080 | 2070 | 2075 | 2070 | 2080 | 2060 |

From a study of the data in table 1, it can readily be seen that uniform and consistent results can be obtained.

Pyrometric Cones.—Besides controlling the temperatures by the use of pyrometers, cones 8, 9 and 10, placed on top of every other ear, are also used. Figure 5 plainly shows the condition of cones 8, 9 and 10 for a period of four days. Again the uniformity obtainable in the kiln is plainly shown.

Porosity.—Porosity tests of the biscuited ware from all sections of the ears were made to determine the actual effect of the above conditions on the density of the ware. Table 2 gives the average per cent porosity of the ware taken from the top of the cars during a 24-hour period.

TABLE 2

| Time car was drawn | Porosity per cent | Time car was drawn | Porosity per cent |
|-----------------------|----------------------|-----------------------|----------------------|
| 6.00 A.M..... | 5.8 | 6.00 P.M..... | 6.3 |
| 7.30 A.M..... | 6.2 | 7.30 P.M..... | 6.8 |
| 9.00 A.M..... | 6.1 | 9.00 P.M..... | 5.1 |
| 10.30 A.M..... | 6.3 | 10.30 P.M..... | 5.4 |
| 12.00 Noon..... | 6.8 | 12.00 Midnight..... | 5.8 |
| 1.30 P.M..... | 7.4 | 1.30 A.M..... | 6.3 |
| 3.00 P.M..... | 7.2 | 3.00 A.M..... | 6.8 |
| 4.30 P.M..... | 7.1 | 4.30 A.M..... | 7.3 |

From the data in table 2 it can be seen that we obtain just as



FIG. 5.—Cones 8, 9 and 10 for a period of four days.

uniform a porosity or density of the ware as would be expected from the temperatures and the conditions of the pyrometric cones as given above.

In table 3 we tabulate the porosity of the ware from the four corners of the top of two different cars. These results are typical of the conditions obtained from day to day and give an idea of the uniformity of the ware from side to side of the car. Furthermore, these results hold good regardless of the height of the horizontal plane from which the trials are taken, that is, the density of the ware on the bottom of the car is just as uniform from side to side as that on top of the car as shown by the data in table 4. As

TABLE 3

| | Front. per cent | Rear. per cent | Front. per cent | Rear. per cent |
|-----------------|--------------------|-------------------|--------------------|-------------------|
| Right side..... | 7.2 | 7.5 | 6.7 | 6.5 |
| Left side..... | 7.1 | 7.6 | 6.6 | 6.3 |

has been stated before, the only appreciable difference in the porosity or density of the ware occurs between the top and bottom of the car. However, the writers wish to emphasize one point, that the slight variation in heat distribution (although just as good if not better than the average conditions in periodic kilns) as indicated from the porosity tests is not due to inability to procure a better penetration of the heat in the Dressler kiln, but the fault lies wholly with local conditions. The sagger cars decreased the capacity of the kiln to a point where it was necessary to increase the car schedule beyond the point where it was possible to obtain a better distribution of the heat. This bad feature we are certain will be eliminated just as soon as the saggerless cars are installed. The car schedule can be decreased, if necessary, and still have a greater capacity than is possible with sagger cars on a $1\frac{1}{2}$ -hour schedule.

A test run was made with the cars on a two-hour schedule which allowed the ware to remain in the soaking zone for approximately 5 hours instead of $3\frac{1}{2}$. The average porosity for this run is recorded in table 4. The difference in porosity in this instance between the top and bottom of the car being only 1.1 per cent, one could not wish for better results than these.

TABLE 4

| | Sagger No. | Porosity per cent |
|--------|------------|----------------------|
| Top | 1..... | 5.0 |
| | 2..... | 4.9 |
| | 3..... | 5.2 |
| | 4..... | 5.6 |
| | 5..... | 5.8 |
| | 6..... | 6.0 |
| Bottom | 7..... | 6.1 |

Structural Features

Tracks.—Aside from the above details of operation there are several structural features which may indirectly affect the results.

Too much stress can not be placed upon the necessity of having all tracks leading to and away from the kiln laid on solid foundations and all joints made in such a way as not to give the car loaded with ware the slightest jolt as it passes over the rail joints and onto the transfer car. Especially is this imperative at the mouth of the kiln where the green ware passes over the tracks. If a car of green ware is given a number of slight bumps as it is transferred from the placing tracks to the kiln, the biscuit losses will be high. This jolting will invariably sprain the ware in the bottom of the bungs. Therefore, all tracks should be laid down with precision and care.

Ante-chamber.—In case an increase capacity over that obtained with saggerless cars on a two-hour schedule is desired we recommend the addition of about 30 feet of ante-chamber to the mouth of the kiln. The addition of this extra 30 feet would make it possible to increase the soaking zone at least 5 feet, making a total of 20 feet, which in our judgment would be sufficient to obtain a very even heat distribution under average operating conditions. Besides the ware would be brought to the maximum temperature more slowly which is to be desired as it removes the possibility of fire cracking by a too rapid expulsion of the water.

Exit-chamber.—The writers would also suggest the addition of an extra 30 feet to the exit end of the kiln. In case this is done, dunting would be entirely eliminated. The cost of constructing this extra 60 feet would be comparatively small as there would be no necessity for insulation. A 9-inch brick wall on the sides and a $4\frac{1}{2}$ -inch arch overhead would be ample. This cost would be more than offset by the increased heat distribution and the decreased dunting.

Cost of Operation

It is to be regretted that the writers are unable at this time to give complete cost data on the operation of the Dressler tunnel kiln, due to the fact that a number of changes which directly affect the costs have been made and are being made today. Even though a complete unit is not in operation we can give some

data which will show the decreased cost of production by the use of the tunnel kiln.

Fuel.—We are now using $3\frac{1}{2}$ tons of coal per 24 hours for firing 16 cars of biscuit ware. Furthermore, this consumption will not be increased when saggerless cars are used as the heat now used in heating up the sagger will be used in firing the increased amount of ware. Therefore, with saggerless cars which list at \$325 each, and on a $1\frac{1}{2}$ schedule, or 16 cars a day, the fuel consumption will be $3\frac{1}{2}$ tons for every \$5,200 ($\325×16) worth of ware, which is approximately what a good-sized periodic kiln lists at. But the fuel consumption of a periodic kiln is about 17 tons on the average, making a difference in coal consumption of about $2\frac{1}{2}$ tons per \$1000 list. With coal at \$4.25 per ton the saving will be \$9.50 for every \$1000 worth of ware.

Labor.—Under our peculiar present conditions of operation no saving in the labor cost has been made. But when once certain labor difficulties have been overcome and a complete unit has been installed there certainly will be a considerable decrease in the labor costs. What this decrease will be we can not say, for any figures on the labor costs that we might give would be pure and simple guess work and, therefore, useless.

Saggers.—As has been shown from our preliminary tests of the saggerless car, the cost of saggers will be materially decreased. For our first saggerless car although crudely made, has been in continuous use for over five months, being through the kiln 34 times, has had no repair, but is still in good shape and looks as if it was good for five more months. Therefore, the life of a saggerless car when properly constructed should be at least one year without repair. This means a great saving in the cost of the refractory material used for setting the ware in the kiln.

Exhaust Heat.—Another factor which will affect the comparative cost of production in the Dressler kiln *versus* the periodic kiln is the exhaust heat from the cooling pipes in the tunnel kiln. This heat can very readily be utilized in winter for heating the building and, therefore, make quite a saving in the fuel necessary to heat the biscuit warehouse, or gloss warehouse.

Conclusions

In conclusion we can conscientiously state that at the Limoges China Company it has been definitely proven beyond any question of doubt that a greater uniformity of product at a far less cost can be produced in the Dressler tunnel kiln than is possible in any type of periodic kiln in use today in the manufacture of semi-porcelain.

SEBRING POTTERY CO.
SEBRING, OHIO

NOTICE.—*Further discussion of this subject is solicited. All communications should be addressed to the Editor.*

THE COMPOSITION OF KILN GASES AND THEIR EFFECT ON TERRA COTTA GLAZES AND COLORS¹

BY F. B. ORTMAN

Every manufacturer of architectural terra cotta is aware of the difficulties attendant upon any effort to standardize the various processes employed in his business, the very nature of which is such as to peculiarly resist efforts along this line. It not infrequently happens that attempts to reproduce former satisfactory results, fail, even though apparently all conditions remain exactly the same.

The kiln-burning is the process which usually comes in for the lion's share of the blame when such things happen, partly because it is the operation which uncovers all the errors and failures of the preceding operations, but largely because it is the process wherein direct control of, or contact with the material is, more nearly lost than in any other. Considerable has been written about terra cotta kilns, their design, construction, operation, etc.; but most of this has been directed toward the economical attainment of uniform heat-treatment, and the taking care of the major chemical changes such as dehydration, oxidation, etc., without very much regard to minor chemical reactions which may be taking place here and there throughout the kiln and which if not properly provided for or guarded against, many result in very unsatisfactory results.

It is not the intention of this paper to attempt to supply this deficiency, but rather to present a few notes on the result of an investigation on one or two of these minor changes, which are apt to be prolific sources of trouble.

Sulphuring

Nature of Trouble.—This phenomenon is one of the most frequent sources of trouble with which the manufacturer has to

¹ Received February 27, 1920.

contend, in producing glazed material. It may result in bubbling, blistering, pin-holing or scumming, depending upon the amount involved and the time and conditions under which the action takes place. The nature of the defects produced has been discussed at length by Seger (Vol. 2, page 583, Collected Writings), Burt (Vol. 2, page 139, T. A. C. Soc.) and others and will not be repeated here.

TABLE 1—SHOWING PER CENT OF SO_3 CONTAINED IN SAMPLES OF ENAMEL DRAWN FROM VARIOUS KILNS AT DIFFERENT TEMPERATURES

| Temp. Degrees C | Kiln 29 Per cent SO_3 | Kiln 28 Per cent SO_3 | Kiln 26 Per cent SO_3 |
|--------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| 700 | 1.83 | 2.29 | 0.60 |
| 725 | 1.92 | .. | .. |
| 750 | 2.00 | .. | .. |
| 775 | 3.37 | 3.28 | 3.95 |
| 800 | 3.12 | .. | .. |
| 825 | 2.29 | 2.31 | 2.78 |
| 850 | 2.33 | .. | .. |
| 875 | 1.94 | .. | .. |

Investigation Made.—In an effort to obtain a little more information on the source, quantity, time and method of attack of this destructive agent in connection with the burning of terra cotta, an investigation was conducted over a period of several months on several different terra cotta kilns of the usual round, up-and-down draft, muffle type.

Presence of Sulphur.—Obviously the first step in the investigation was to prove the presence of sulphur in the enamel or glaze during the burning process. This was done by glazing a number of draw trials with a glaze free from sulphur and drawing them periodically up to about 875°C , or until the glaze became too hard, scraping off the glaze and analyzing it for sulphur.

The results of this analyses (table 1) showed clearly that the glaze did absorb an appreciable amount of sulphur trioxide in each of three different kilns, the maximum content (within the range covered) being at about 775°C .

Source of Sulphur.—The presence of sulphur in the glaze having been clearly indicated, the next step was to investigate the source. Since the enamel had been found to be free of sulphur

before going into the kiln (only a trace having been found on analysis), obviously the sources of same must be directly connected in some manner with the kiln-burning process. Of these there were the following possibilities:

(A) *Clay*.—The clay being used was known to contain a certain amount of sulphur both in the form of sulphates and as iron pyrites. In the case of the latter about one-half of its sulphur is distilled off as SO_2 at about red heat, the final amount not leaving until about 900°C . An average of several analyses of the clay being used at the time disclosed 0.048 per cent SO_3 and 0.038 per cent S (non-oxidized). While this would not be considered abnormally high, it is evident that the amount of sulphur driven off in a kiln of from 30 to 50 tons capacity, must be reckoned with, especially, when it is highly probable that the major portion of it leaves in a comparatively short time.

(B) *Grog*.—The importance of this material as a source of sulphur is largely dependent upon its porosity and the length of time and conditions under which it has been exposed to the weather. Freshly burned grog or vitreous grog may be considered practically free of sulphur. On the other hand, porous grog such as "overs," old fire brick, saggars, etc., when exposed to the weather may contain a considerable percentage of SO_3 , no doubt absorbed from the rain which has passed through smoky atmosphere. Samples of terra cotta "overs" which have weathered for four or five years have been found to contain as high as 0.10% SO_3 on analysis.

(C) *Coal*.—The coal being used was that known as Indiana gas coal, the sulphur content of which varies greatly, but could not be considered abnormally high. An average of several analyses made at the time showed a total sulphur content of 0.80 per cent S. Theoretically, of course, in a muffle kiln (if the muffle were entirely impervious to gas), the presence of sulphur in the coal would have no effect on the atmosphere within the kiln chamber. Practically, however, as every kiln burner knows, it is impossible to exclude all the gases of combustion from the kiln chamber. This is shown conclusively by analyses of the kiln gases for sulphur (see table 2), where appreciable amounts of SO_2 are found present at the very early stages of the burn— 200°C to 300°C —

or long before the first of the sulphur is distilled from the clay. The only possible source of this sulphur is from the products of combustion. That we have then, to reckon with the sulphur in the coal, there can be no doubt.

Quantity of Sulphur.—There exists then these two main sources of sulphur, *viz.*, clay and coal. The next logical step in the investigation was to determine, if possible, quantitative relationship in the sulphur content of the kiln gases, from one stage to another of the burn, as influenced by these two factors, with a view of adopting corrective measures where possible. The first efforts along this line consisted of an estimation of the SO_2 in the kiln gases and combustion gases, periodically during the burn.

Bromine Absorption.—The method adopted was to draw a volume of five gallons of gas in each instance, allowing same to bubble through a series of flasks containing bromine water forming H_2SO_4 , which was later precipitated as BaSO_4 and calculated to milligrams of SO_3 per 5 gallons of gas. These samples were drawn simultaneously from the kiln chamber, and from the flue gases, in order to determine what relationship, if any, might exist between the sulphur content of the gases from the two sources.

Typical results of these experiments, which were conducted on several different kilns are shown in table 2, for a coal-fired kiln and table 3 for a producer-gas fired kiln.

TABLE 2—SHOWING MILLIGRAMS OF SO_3 PER 5 GALLONS OF KILN GAS AND COMBUSTION GAS AT VARIOUS TEMPERATURES OF TYPICAL BURN—DIRECT COAL-FIRED KILN

| Temp. Degrees C | SO_3 in muffle mgm. in 5 gal. | SO_3 in flue mgm. in 5 gal. |
|--------------------|---|---|
| 100 | .. | 1.064 |
| 200 | .. | 10.000 |
| 300 | 1.270 | .. |
| 400 | 3.260 | 8.580 |
| 500 | 0.789 | 22.780 |
| 600 | 0.861 | 5.733 |
| 700 | 7.100 | 27.570 |
| 800 | 3.780 | 2.400 |
| 900 | 27.570 | 4.460 |
| 1000 | 19.950 | 9.950 |

TABLE 3—SHOWING MILLIGRAMS OF SO_3 PER 5 GALLONS OF KILN GAS AND COMBUSTION GAS AT VARIOUS TEMPERATURES OF TYPICAL BURN OF KILN FIRED WITH PRODUCER GAS

| Temp. Degrees C | SO_3 in muffle mmg. in 5 gal. | SO_3 in flue mmg. in 5 gal. |
|--------------------|---|---|
| 100 | ... | ... |
| 200 | None | 5.3 |
| 300 | Trace | 0.82 |
| 400 | Trace | 4.98 |
| 500 | 3.2 | 12.53 |
| 600 | None | 2.13 |
| 700 | None | 2.13 |
| 800 | 2.4 | 11.87 |
| 900 | 15.86 | 3.78 |
| 1000 | ... | ... |

From these it will be seen that the attempt to establish a quantitative relationship between the SO_3 in the flue gas and that in the kiln chamber for the temperatures below red heat was only partially successful. Generally speaking, the curves would follow the same general trend, but the relationship is not at all decisive. It would hardly be expected to be otherwise, however, as during this time all trial holes are open and the kiln chamber is well ventilated. Table 2 does show, however, as pointed out on page 479, that SO_3 is present in the kiln chamber long before any sulphur leaves the clay

Another interesting fact is brought out by comparing the results on a direct coal-fired kiln (table 2) with those on a producer-gas-fired kiln (table 3). Note that below 900°C , when all the sulphur leaves the clay, the quantity of SO_3 in the kiln seems to be considerably less for the producer gas-fired kiln than for the direct fired kiln. This difference was apparent on every producer gas-fired kiln examined, and is probably due to the more uniform-firing conditions and muffle wall temperatures which obtain with the former method. In direct firing there is a sudden cooling of the muffle walls each time a fresh charge of coal is fired, which tends to open up the joints and cracks more than usual. Coincident with this, the flue spaces are all crowded or choked with excessive volumes of hydrocarbons and other volatile gases from the coal causing an abnormal pressure inward at this particular time, which results in excessive infiltration of the gases of com-

bustion. That this condition exists, was demonstrated a number of times by analyses of samples taken at different times with respect to the time and manner of firing. In the gas-fired kilns, obviously it does not obtain.

Lime Absorption.—In order to get still further information on the relative intensity of the sulphuring action during the progress of the burn a second series of experiments was conducted as follows: A small sample of hydrated lime was introduced into the kiln chamber at a distance of about 15 inches from the muffle at the beginning of the burn and was withdrawn when the kiln reached 100°C , and a fresh sample substituted and left till 200° was reached, when another sample was introduced, and so on throughout the entire period of the burn. Each sample was then analyzed for SO_3 . It was believed that from the beginning up until the glaze was fused the rate of absorption of SO_3 by the lime would be indicative of, or correlative with, the action of the same gas (SO_3) on the glazes.

TABLE 4—SHOWING AMOUNT AND RATE OF ABSORPTION OF SO_3 BY HYDRATED LIME DURING TYPICAL BURN

| Hrs. | Temp. Degrees C | Per cent SO_3 in sample | Rate of absorption, per cent in 10 hrs. |
|-----------------|--------------------|--|--|
| 12 | 100 | 0.14 | 0.116 |
| 32 | 400 | .26 | .37 |
| 43 | 500 | .80 | .90 |
| 49 | 600 | .83 | 1.40 |
| 55 | 700 | .83 | 1.40 |
| 65 | 800 | 3.92 | 3.92 |
| 71 | 900 | 8.01 | 7.30 |
| $85\frac{1}{2}$ | 1000 | 14.13 | 14.00 |
| 99 | 1050 | 14.3 | 11.0 |

TABLE 5—SHOWING SQUARE INCHES OF VENTILATING OPENINGS, TOP, BOTTOM AND TOTAL, FOR SAME BURN AS IN TABLE 4

| Time interval | Temp. interval $^{\circ}\text{C}$ | Sq. in top | Sq. in bottom | Total |
|-------------------|-----------------------------------|------------|---------------|-------|
| 0 to 47 hrs. | 0° to 570° | 276 | 190 | 476 |
| 47 to 57 hrs. | 570° to 720° | 84 | 190 | 274 |
| 57 to 68 hrs. | 720° to 830° | 20 | 190 | 210 |
| 63 to 74 hrs. | 830° to 890° | 20 | 100 | 120 |
| 74 to 84 hrs. | 890° to 980° | 20 | 10 | 30 |
| 84 to 95 hrs. | 980° to 1030° | 26 | 10 | 36 |
| 95 hrs. to finish | 1030° to 1050° | 26 | 0 | 26 |

From the quantity absorbed by each sample a *rate of absorption* was then computed in terms of per cent in 10 hours, and a typical result given in table 4.

Kiln Ventilation.—At this point it became evident that the method of ventilating the kiln chamber must necessarily have a very important effect on the extent of sulphuring action which takes place, and a study was made of the ventilating schedule of the same kiln. The only means available for expressing this ventilation, in quantitative terms, was in computing the area of the openings into the kiln chamber during the burn. These openings were divided into two classes—the bottom openings, through which fresh air was admitted, and the top or crown openings, through which the kiln gases were expelled. Table 5 shows the result of this computation. In order to facilitate the study of these conditions and their relation to each other chart 1 was prepared, on which, in addition to the usual time-temperature curve, are plotted curves representing the *rate of absorption* of SO_3 by lime (per cent in 10 hours), and the square inches of openings, bottom, top and total for ventilation.

Effect of Ventilation on SO_3 in Kiln.—A study of these curves brings out several interesting points.

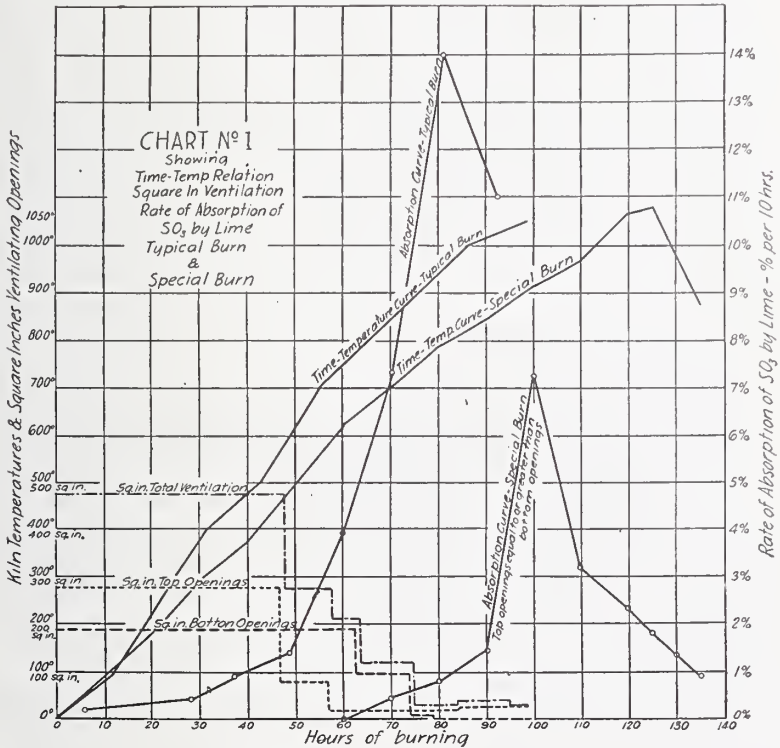
First: It is evident that the amount of SO_3 absorbed prior to the time the clay begins giving off its sulphur is almost negligible in amount, in this instance. If, however, condensation were to take place during water smoking an appreciable amount of sulphuric acid would be deposited.

Second: It is important to note that as the ventilating curves drop, the absorption curves mount. It is not to be inferred that the *former* is the *whole* cause of the latter. After red heat is reached the rapid distillation of the sulphur from the clay would greatly influence the rise in the absorption curve, independent of the ventilation. It is clear, however, that in this particular instance the ventilation is sharply reduced at a very unfortunate time, and it seems reasonable to conclude that the rate of absorption would have been kept very much lower if such had not been the case.

Third: It would seem that the effective ventilating openings would be those in the crown, and that, therefore, they should always

be kept equal to or greater than the bottom openings. In this instance after forty-eight hours the reverse is true.

Numerous experiments were then conducted with a view to reducing the amount of sulphur present by revising the ventilating schedule. These were only partially successful, however, as indicated by curve on chart 1, owing to encountering very serious



practical difficulties in maintaining satisfactory and uniform progress with the kiln, when the ventilation was carried too far. Weather and other variable conditions renders it impossible to predict in advance, in any except the most general terms, what the ventilating schedule of any particular kiln should be. The dangerous periods having been determined, it becomes the kiln burners problems on each kiln to provide the maximum ventila-

tion at these times, with a minimum of detriment to the kiln's progress. One point, however, was very clearly established, *viz.*, the necessity of adequate stack draft and flue capacity so that any difference in pressure that may exist between the kiln chamber and the flue will be exerted *outward* rather than *inward*.

Effect After Glaze Fusion.—During the course of this investigation the question arose as to whether the presence of SO_3 was destructive after fusion of the glaze. To determine this, a small, freshly glazed unburned trial was enclosed with a previously burned trial of the same glaze, in a closed sagger into which were also introduced considerable pyrites grains. The piece being burned for the first time was entirely ruined, while the previously burned piece came out unchanged, from which it would seem that after fusion of the glaze has taken place, the SO_3 has little or no effect, except of course, in the event that all of the gases have not been previously expelled from the body, or that conditions become reducing causing glaze to liberate sulphurous acid previously absorbed.

Conclusions.—A study of the data obtained by these experiments would seem to justify the following conclusions:

First: That there exists within the kiln chamber, in contact with the ware, an appreciable amount of SO_3 gas practically from start to finish of the burn.

Second: That the source of this is from a leakage of combustion gases through the muffle wall, up until about red heat when the sulphur begins to distill from the pyrites in the clay.

Third: That owing to the excessive ventilation prevailing at the beginning of the burn, the SO_3 is removed rapidly and does little damage.

Fourth: That after the glaze has fused it is not easily susceptible to chemical action of SO_3 upon its surface.

Fifth: That the danger zone, therefore, lies between red heat and the time of fusion of the glaze, and is particularly troublesome because the sulphur being distilled as SO_2 from the pyrites in the clay encounters a moist atmosphere due to the dehydration of the clay forming H_2SO_4 and at a time when the ventilation is apt

to be sharply reduced by the closing of trial holes and crown openings.

Sixth: The sulphuric acid gas thus formed may be taken up by the glaze, either by physical absorption or chemical combination or both, and exert its destructive action in any of the following manners:

(A) Upon fusion of the glaze, SO_2 may be displaced by SiO_2 and escaping as a gas cause blisters. (Seger's Collected Writings, Vol. 2, page 647.) The extent of this action would be influenced by the silica content of the glaze and its tendency to dissolve silica from underslips or body. Seger found that a bi-silicate would hold 4 per cent of H_2SO_4 in solution while a tri-silicate would hold only 2 per cent. There is, therefore, a certain amount of SO_2 and O to be expelled from the glaze saturated with H_2SO_4 whenever that glaze takes up any silica from the body or under-slip.

It is probably not necessary, however, that the glaze be saturated with sulphates, in order that SO_2 may be given off, especially if the kiln atmosphere becomes reducing. That such may be the case especially toward the end of the burn will be shown later, and no doubt herein lies the explanation of occasional blistering troubles. The glaze during the progress of the burn may have absorbed considerable H_2SO_4 from the kiln atmosphere but still be well below its saturation point. Fusion takes place and the glaze remains tranquil as long as oxidizing conditions prevail. However, if the kiln atmosphere then becomes reducing, especially at that high temperature, the H_2SO_4 and other sulphates are broken up and SO_2 and O in escaping, or attempting to escape, through the molten glaze form blisters or produce a scummy appearance.

(B) The sulphuric acid may displace boric acid (B_2O_3) from glazes containing same.

(C) H_2SO_4 may react with coloring oxides and other fluxes present, thus preventing maturity necessary for proper development of desired color and texture.

Seventh: The chances of trouble in this period may be very much lessened by:

(A) Providing the maximum ventilation possible consistent with satisfactory progress of the kiln.

(B) Firing so as to avoid choking the flues with large volumes of gas.

(C) Maintaining adequate secondary air supply in the fire boxes.

(D) Maintaining adequate stack draft and oxidizing conditions throughout.

Effect of Reducing Conditions

The necessity for maintaining oxidizing conditions through the burn is so well recognized by the terra cotta manufacturer that he is apt to take it for granted that his kiln atmosphere is always safely oxidizing. Such, however, may not prove to be the case, and an examination in connection with trouble such as color variation on both glazed and standard material, fading or loss of color on glazes, occasional blistering or scumming, etc., may disclose that his kiln atmosphere is quite frequently apt to be deficient in oxygen.

During the course of the above investigation frequent Orsat analyses were made of both the combustion gases and the gases within the kiln itself. While results of these analyses would vary somewhat from one kiln to another or with weather conditions for the same kiln those shown on chart 2 indicate the general tendency, which is to approach dangerously close, and in some cases obtain, reducing conditions the last few hours of the burn.

Numerous experiments were made in the method of firing, of introducing the secondary air in the combustion gases, of ventilating the kiln chamber proper, etc. While some improvement was noted as a result of careful study of these conditions, uniformly satisfactory conditions were not obtained until the stack draft was decidedly increased by raising and enlarging the stacks.

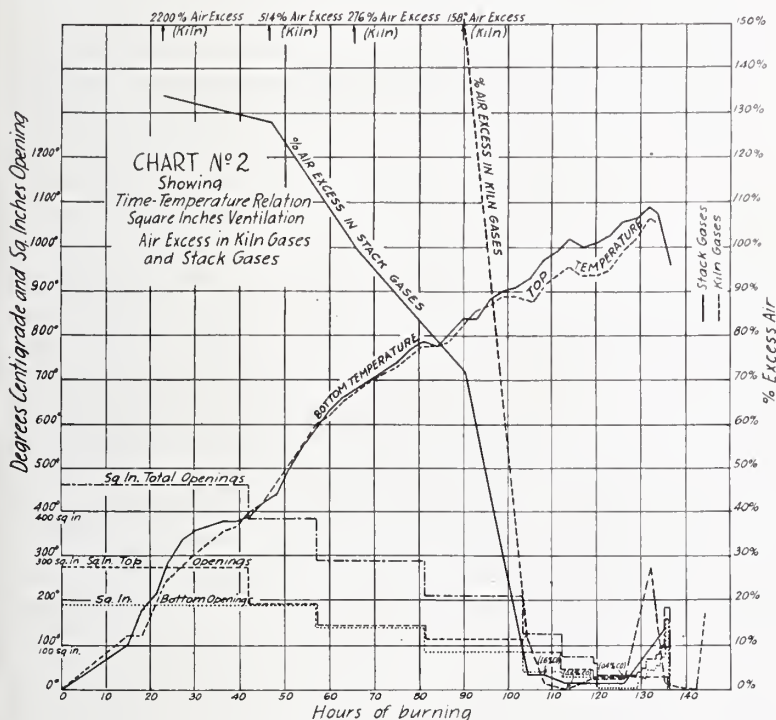
The details of these experiments and the resulting data have been omitted for brevity, but they brought out very clearly the following interesting points:

First: That it is impractical to depend entirely upon direct admission of air through trial holes or other openings for main-

tenance of oxidizing conditions, without retarding the progress of the kiln beyond practical limits.

Second: That after closing of all the trial holes and other openings into the kiln the oxygen is consumed very rapidly.

Third: That the oxygen is consumed much faster when the gases of combustion are allowed to become reducing or near reducing.



Fourth: That once the oxygen has been exhausted in the kiln chamber it is very difficult if not impossible to re-establish oxidizing conditions by admitting air into the combustion gases.

Fifth: That it is highly essential, therefore, that the combustion gases be kept safely oxidizing throughout, particularly after the trial holes are closed.

Sixth: That the setting up of reducing conditions, particularly after the glaze has fused may produce blistering, scumming, etc.,

on glazed work, by reason of reduction of sulphates previously absorbed and liberation of $\text{SO}_2 + \text{O}$ through the molten glaze.

Seventh: That while the kind of coal, method of firing, construction of fire box and secondary air supply, all have an important bearing on the maintenance of this condition, the first and most important factor is an adequate draft, without which, in the ordinary up-and-down draft muffle kiln, occasional reducing conditions are inevitable.

NORTHWESTERN TERRA COTTA CO.
CHICAGO, ILL.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

FISH-SCALING*¹

By J. B. SHAW

Fish-scaling is a defect very common in sheet steel enameling and practically unknown in any other connection. It is seldom encountered in enameling very heavy steel or cast iron articles. It presents itself in the form of small pits resulting from a speck of ground coat enamel jumping off, usually leaving the bright steel exposed. These pits are usually semi-circular in shape and may be as large as one-fourth inch in diameter. Two general types of fish-scaling are commonly recognized. In one the pits are very small, half the size of a pinhead or less, and are very numerous, covering nearly the entire surface. In the other type, the pits are larger, one-sixteenth to one-fourth inch in diameter, and are not so numerous.

If the ware has much tendency to fish-scale, the defect will usually present itself soon after the first coat is burned; but in case there is little tendency to fish-scale, it is liable to develop if the ware is allowed to stand some length of time after burning the first coat before applying the second. It may not present itself until the ware is run into the furnace for burning the second coat of enamel, when a snapping sound, accompanied by flying chips and black spots on the ware, give notice that the ware is ruined.

Fish-scaling is purely a ground coat defect and very rarely occurs after a second coat has been burned on the ware. It is much more common on heavy gauge (20 to 16) steel than on the lighter gauges (26 to 20). This defect must be sharply distinguished from blistering, which is also quite common in steel enameling and invariably results from impurities rolled into the steel.

* Received February 27, 1920.

¹ By permission Ingram-Richardson Co.

Another common defect in steel enameling somewhat resembling fish-scaling is the pitting which comes on the ground coat, giving it a scabby appearance. This defect is due to use of improper tempering agents which cause rusting under the ground coat in drying, the rust spots reacting vigorously with the enamel in burning, resulting in a spot having the appearance of iron scale. This defect can generally be entirely eliminated by tempering the ground coat with borax in the mill or tub.

In spite of the common occurrence and resultant high losses due to fish-scaling, the subject has received very little serious attention on the part of scientific investigators.

The following outline covers the preliminary experiments in an investigation undertaken by the writer in behalf of the Ingram-Richardson Company. Circumstances beyond our control forced us to stop before arriving at final conclusions, but it is believed the data obtained, point strongly to certain facts hereinafter stated. It may, at least, stimulate some one to further investigation, resulting in benefit to the industry.

Making and Applying Enamels

Object.—The object of the experiments here outlined was to determine how far and in what respect the composition of the ground coat affected fish-scaling.

Ground Covered.—The series of enamels was outlined to cover a wide field of compositions of ground coats of probable value. Silica, alumina and boric acid vary between wide limits. Lead, which is not commonly used, is introduced and fluorspar varies quite widely. Twenty-five frits were made and each frit given five different mill treatments, making in all one hundred twenty-five enamels.

These additions were independent of other additions of raw material mentioned, such as clay, etc. This made a total of 120 enamels, 5 enamels being made from each of the 24 frits.

Preparation.—The frits were all made in crucible batches of about 700 grams. They were ground dry to pass a 40-mesh screen. Those containing lead ground very much more easily

BATCH WEIGHTS

| No. | Feldspar | Flint | Borax | Soda | Niter | Fluor-spar | Lead oxide | Cobalt oxide | Manganese dioxide |
|---------|----------|-------|-------|------|-------|------------|------------|--------------|-------------------|
| 1..... | 84 | 54 | 76.4 | 30 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 2..... | 84 | 54 | 152.8 | 8.5 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 3..... | 84 | 54 | 76.4 | 30 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| 4..... | 84 | 54 | 152.8 | 8.5 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| 5..... | 84 | 6 | 76.4 | 30 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 6..... | 84 | 6 | 152.8 | 8.5 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 7..... | 84 | 6 | 76.4 | 30 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| 8..... | 84 | 6 | 152.8 | 8.5 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| 9..... | 168 | 0 | 76.4 | 13.8 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 10..... | 168 | 0 | 152.8 | 0 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 11..... | 168 | 0 | 76.4 | 13.8 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| 12..... | 168 | 0 | 152.8 | 0 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| clay | | | | | | | | | |
| 13..... | 84 | 38.7 | 76.4 | 30 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 14..... | 84 | 38.7 | 152.8 | 8.5 | 8.5 | 16 | 0 | 2.5 | 8.7 |
| 15..... | 84 | 38.7 | 76.4 | 30 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| 16..... | 84 | 38.7 | 152.8 | 8.5 | 8.5 | 0 | 44.6 | 2.5 | 8.7 |
| flint | | | | | | | | | |
| 17..... | 84 | 34 | 76.4 | 30 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| 18..... | 84 | 34 | 152.8 | 8.5 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| 19..... | 84 | 6 | 76.4 | 30 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| 20..... | 84 | 6 | 152.8 | 8.5 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| 21..... | 168 | 0 | 76.4 | 13.8 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| 22..... | 168 | 0 | 152.8 | 0 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| clay | | | | | | | | | |
| 23..... | 84 | 38.7 | 76.4 | 30 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |
| 24..... | 84 | 38.7 | 152.8 | 8.5 | 8.5 | 16 | 44.6 | 2.5 | 8.7 |

1-A, 2-A, etc. = 10 per cent flint added to 1, 2, etc.

1-B, 2-B, etc. = 20 per cent flint added to 1, 2, etc.

1-C, 2-C, etc. = 10 per cent calcined kaolin added to 1, 2, etc.

1-D, 2-D, etc. = 20 per cent calcined kaolin added to 1, 2, etc.

than the others and were more finely ground. German V clay was made into a slip and added in this form just as the enamel was prepared for dipping. All mixtures were ground together in a mortar, 8 per cent clay and 3 per cent boiled borax being constant. Additions of flint and calcined clay were ground in a mortar with the frit. In some cases these mixtures were not sufficiently well ground, and particles of raw material made the finished enamel rough. In no case was this serious enough to spoil results.

EMPIRICAL FORMULAS

| No. | KNaO | CaO | PbO | Co ₃ O ₄ | MnO ₂ | Al ₂ O ₃ | SiO ₂ | B ₂ O ₃ |
|---------|------|------|-----|--------------------------------|------------------|--------------------------------|------------------|-------------------------------|
| 1..... | 0.68 | 0.20 | 0.0 | 0.02 | 0.10 | 0.15 | 1.8 | 0.40 |
| 2..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 3..... | ... | 0 | .20 | ... | ... | ... | ... | .40 |
| 4..... | ... | .20 | 0 | ... | ... | ... | ... | .80 |
| 5..... | ... | .20 | 0 | ... | ... | ... | 1.0 | .40 |
| 6..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 7..... | ... | 0 | .20 | ... | ... | ... | ... | .40 |
| 8..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 9..... | ... | .20 | 0 | ... | ... | .30 | 1.8 | .40 |
| 10..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 11..... | ... | 0 | .20 | ... | ... | ... | ... | .40 |
| 12..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 13..... | ... | .20 | 0 | ... | ... | ... | ... | .40 |
| 14..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 15..... | ... | 0 | .20 | ... | ... | ... | ... | .40 |
| 16..... | ... | ... | ... | ... | ... | ... | ... | .80 |
| 17..... | .57 | .17 | .17 | .016 | .08 | 12.5 | 1.5 | .33 |
| 18..... | ... | ... | ... | ... | ... | ... | ... | .66 |
| 19..... | ... | ... | ... | ... | ... | ... | 0.84 | .33 |
| 20..... | ... | ... | ... | ... | ... | ... | 0.84 | .66 |
| 21..... | ... | ... | ... | ... | ... | 2.5 | 1.5 | .33 |
| 22..... | ... | ... | ... | ... | ... | 2.5 | 1.5 | .66 |
| 23..... | ... | ... | ... | ... | ... | ... | 1.0 | .33 |
| 24..... | ... | ... | ... | ... | ... | ... | ... | .66 |

Trials.—All enamels were applied by dipping on 16-gauge and 26-gauge flat sheets and on small basins made of about 24 gauge. Some of the enamels were applied to American ingot iron.

Burning.—All trials were burned in a small muffle which was notter at one end than the other. Because of this it was quite impossible to get the same heat on both ends of a sheet. This proved quite satisfactory however, because it gave over burning, good burning and under burning of the same enamel on different parts of the same sheet, which facilitated studying of the results.

The temperature of the muffle was regulated so that it averaged as nearly as possible to 900 degrees C, or 1650° F. The time required to burn the samples under these conditions varied from 2 to 4 minutes, depending upon the weight of the steel and fusibility of the enamel.

Results

Fusibility.—All enamels with high boric acid and high lead are decidedly more fusible than the others.

The softest and best looking enamels are Nos. 8 and 16. Many of these enamels look good as ground coats.

High alumina hardens the enamel slightly, but no important difference can be noted between those high and low in Al_2O_3 .

Addition of silica (flint) in the mill hardens the enamels very materially.

Addition of calcined kaolin not only hardens the enamels but gives them a dead surface and makes them burn off badly. All enamels marked C and D are decidedly inferior.

General Appearance.—All enamels containing the highest amount 0.80 of boric acid look best. Numbers 5-7-11-15-19 burn off in spots. Others might have done this under other conditions; but this seems to indicate that high lead and low boric acid is a bad combination. This same defect persists when flint is added to these frits. On account of this defect, the following enamels are ruled out, 7, 11, 15, 7A, 11A, 15A, 19A, 11B, 15B, and 19B. Number 1 did not give good results either with or without flint; it was too coarsely ground, which might account for its appearance.

Burning Off of Edges.—This defect is not serious in any case; it is slightly worse on the light steel and is somewhat less noticeable on enamels containing raw flint than those containing none. The low temperature at which these trials were burned probably saved the edges of many of them.

Fish-Scaling.—After allowing the trials to stand for a day, some of each enamel were placed in a vessel and subjected to rapid change of temperature by running first hot and then cold water over them. This was repeated several times, the object being to produce fish-scaling if possible. After standing for one year, only five enamels show any fish-scale at all, these being as follows: No. 12 on Armco and Bessemer where apparently perfectly burned; No. 12A on Armco and Bessemer where burned correctly

but slightly worse where underburned; No. 12B on Armco and Bessemer and open hearth (wash basin), where properly burned; No. 11, on Bessemer where properly burned; No. 11A, on Bessemer where properly burned.

A point of interest here is that 12C and D have not yet developed fish-scale. Number 12 on Armco developed fish-scale the day after burning. Aside from these cases, no fish-scaling is yet in evidence. It will be noted that 11 and 12 are high in alumina and silica and both are lead enamels. Number 12 is probably as good an enamel as any in the lot so far as general appearance goes, while No. 11 has been ruled off because of burning off in spots.

Effect of Flint.—The addition of flint hardens the enamel in every case; it would probably prevent the burning off of enamel on ware having this tendency, as for example, cooking ware having ears or handles. All enamels here which are good without flint are good with as high as 20 per cent.

Effect of Calcined Kaolin.—This has not been beneficial in any case and in most cases has proven detrimental insofar as the appearance of the enamel is concerned. It acts similar to flint in hardening the enamel and further tends to cause the enamel to burn off before it is properly burned. It is probable that it affects fish-scaling, samples C and D, not yet having developed this defect. So far as observations thus far made are concerned, there is not likely to be any beneficial results derived by the use of calcined kaolin.

The results obtained in the laboratory were surprising. It was expected that a majority of the enamels would show fish-scaling, but after standing a year and a half, only five of the enamels prepared in the laboratory show it. This, in spite of the fact that the enamels were applied in thick and thin coats, on different grades of heavy and light steel, and burned to various degrees of maturity in order that every opportunity might be afforded for developing the defect under consideration.

Results Obtained in a Factory

After studying the results of the laboratory experiments, the following formulas were run in the factory in 500-pound batches: Nos. 4-4B, 6-6B, 8-8B, 10-10B, 12-12B, 16-16B, 20-20B, 23-23B.

These enamels all give nice, smooth ground coats when made up in the regular factory practice; but the point of chief importance is that while, after standing a year and a half only two of them, 12 and 16, show any fish-scale on trials made in the laboratory, everyone of them develops some fish-scale as made in the factory and applied to 18-gauge steel. Some are very bad; others show only a slight amount. Number 23 is the best in this respect, and burned to a very smooth ground coat. Even it, however, showed a slight tendency to fish-scale.

Conclusions

The results obtained in the laboratory would lead to the conclusion that the chemical composition of the enamel has very little bearing on the subject of fish-scaling. When the laboratory results, where no fish-scaling is obtained, are considered in the light of the factory results, where all of the formulae show fish-scaling, the above conclusion would seem to be greatly strengthened. If it is established that the chemical composition has little bearing on the cause and control of fish-scaling, that in itself represents a long step toward the solution of the problem.

If the chemical composition of the enamel is eliminated, what other source for the trouble exists? Several might be mentioned. 1. Composition of the steel is frequently blamed. 2. Cleaning and preparation of the steel.¹ 3. Mechanical manipulation in applying the enamel. 4. Fritting and preparation of the enamel. 5. Burning the enamel. While all of these have been given by different manufacturers as contributory causes, none of them so far as the writer knows, have been seriously studied in a systematic manner, with a view to proving the contention.

Treischel produced evidence which seemed to show pretty conclusively that the strength of the acid in the pickling bath has a positive influence on blistering; but fish-scaling is a defect

¹ Treischel, *THIS JOURNAL*, 2, 774.

distinctly different from blistering. It may be that the two defects are very similar insofar as their cause is concerned. In this series of experiments, the laboratory trials were all pickled in a strong hydrochloric acid solution (10 per cent) while those made in the factory were pickled in dilute sulphuric acid. There is not sufficient evidence here on which to base any conclusions of value but what there is would indicate that the pickling had little bearing on the subject.

Poor steel is a favorite excuse for many enamelers in assigning a reason for fish-scaling. It would seem that it ought not to be a very difficult to prove whether this is true or not. In this series of experiments, three grades of steel were used, Bessemer, open hearth and American ingot iron. The data shows that formula 12, one of the three which developed fish-scaling in the laboratory, shows the defect on all three kinds of steel. Here again, what little data was obtained would seem to indicate that the grade of the steel has little bearing on the subject.

One fact that is universally recognized is that fish-scaling is much more common on heavy gauge (20 to 16) than on light gauge (28 to 20) steel. This was recognized throughout the experiments, both in the laboratory and the factory. It is quite evident that this fact, with all that it signifies, must be considered in the solution of the problem.

Preparation, application and burning of the enamel are all fields capable of containing the main cause of the defect. One point in this connection was touched upon in these experiments. The enamels made in the laboratory were all ground dry, giving enamels with a much smaller percentage of fine material than is obtained in wet grinding. It is possible that further investigation of this point would show this to be one of the chief reasons for the difference in results obtained in the laboratory and factory, and reveal one of the chief causes of fish-scaling. Coarse grinding is quite universally recognized to give best results in ground coats.

Finally, while it is admitted that all the data here obtained is negative in character, still it is believed that not a great amount of additional data of this kind would be required to point to the proper solution of this problem.

It is the belief of the writer that fish-scaling will be found to be due, not to one single cause, but to a combination of contributory causes. The fish-scale seems likely to be a small chip of enamel forced off the steel by the expansion of gas under it. The gas bubbles are always present, whether fish-scaling occurs or not; but when the other conditions are properly combined, fish-scaling occurs. What are these other conditions?

NEW YORK STATE SCHOOL OF CLAY WORKING AND CERAMICS
ALFRED, NEW YORK

 NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

A LINING FOR GLASS POTS¹

By S. R. SCHOLES

It is the purpose of the present paper to describe a process for manufacturing glass pots which renders them less corrodible by the molten glass and extends their useful life, at the same time improving the quality of the glass produced. This process is particularly applicable to pots used in the melting of heavy lead glass containing potash. It is characteristic of potash-lead glass, that while it is not a very good solvent for clay, nevertheless on account of its density and fluidity at the melting temperature it penetrates the interstices of the pot wall, causing the well known "honeycomb" effect. A further result of such action on the pot wall is that it loosens less soluble portions of the wall, usually consisting of grog particles that float into the glass where they appear as stones and cause much loss of production and rejection of otherwise well made ware.

In the attempt to remedy this condition, that is, to produce a pot resistant to the "honeycomb" action of potash-lead glass, it was readily recognized, in accord with the opinion of Seger and other authorities, that the physical rather than the chemical constitution of the pot wall is of greater importance. Porosity tests made by boiling a weighed piece of pot shell in water, cooling it in water, then wiping off the surplus water and re-weighing, showed that the usual pot wall, except portions that have been greatly overburned, has a porosity, expressed in terms of per cent of water absorbed, averaging 10 per cent. It is thus easy to see how a considerable penetration could be effected by melted glass.

The problem then was to reduce this porosity so as to present an impenetrable wall to the glass. It was considered best not to make the entire pot out of non-porous material for the reason that glass pots are subject to such great variations in temperature,

¹ Received February 27, 1920.

and the looser structure of the wall permits expansion and contraction with less danger of fracture. The attempt was made to develop a lining, carried upon a pot wall of the ordinary porous refractory type, which should protect the wall against the attack of the glass.

A refractory clay body having the general character of porcelain is recognized as the least porous that can well be produced. Such a body it was found after some experimentation could be formed from the ordinary glass pot batch by the introduction of feldspar to form a sintering bond between the clay particles producing the phenomenon generally referred to as vitrification. Test pieces made in this way showed less than 1 per cent porosity under the treatment described above. The fragments of such vitrified pieces showed a very small rate of attack by fused sodium carbonate, compared with pot shell.

A choice of suitable composition for the feldspar clay mixture depended entirely upon the temperature at which the pot was to be used. In the first large-scale experiment the mixture of 90 per cent pot batch and 10 per cent feldspar was fixed upon, since this formed a very dense body after burning at 1300°C , yet did not show over burning at that temperature.

The process of applying this lining to the glass pot was simple. The lining mixture, worked up into rolls in the usual manner, was placed along the bottom and sides of the pot, as the latter was built, forming a finger-course about $1\frac{1}{2}$ inch thick up to the metal line and diminishing in thickness, leaving off about 8 inches higher. Because of the fact that the lining material did not differ materially in proportions of raw clay and inert material from the composition of the balance of the pot, no difficulty was experienced in drying the pot, and a homogeneous body was obtained at all times.

The results obtained in using such pots have been very good. Experience has shown that it is often necessary to reduce the proportion of feldspar as much as 5 per cent. After firing in the furnace the lining develops a very dense structure and formation of stones is reduced to a minimum. Also, the attack on the pot wall is greatly retarded so that the useful life of the lined pot is from two to three times that of the ordinary pots, in potash-lead

glass. Moreover, although the lining itself may be entirely dissolved from a certain portion, notably the "knuckle" of the pot, it has by that time protected the wall until the latter has reached a stage of vitrification causing it to be very resistant to corrosion. The only difficulty experienced has been in the formation of cracks in the lining, due to the inability of such dense material to withstand the cooling shocks incident to charging with cold batch. These cracks, while not worse than those ordinarily forming in pots, permit the glass to penetrate into the less resistant pot wall and are really the cause of the final failure of the pots.

These lined pots are easier to handle than pots made entirely of porcelain material because, in the first place, the lining matures readily at the ordinary melting temperatures, and second, because of their more porous structure in the raw condition they may be brought up in the pot arch fully as rapidly as ordinary pots.

The above work was carried on under a fellowship established at Mellon Institute of Industrial Research, Pittsburgh, Pa., and the writer wishes to acknowledge the coöperation of the staff of the Mellon Institute and Mr. W. R. Irvin of the Laclede Christy Company under whose supervision the lined pots were first manufactured.

H. C. FRY GLASS COMPANY
ROCHESTER, PENNA.

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CERAMIC ABSTRACTS

General

The asbestos industry in 1919. O. BOWLES. *Eng. Min. Jour.*, 109, 224-5 (1920).—The following topics are briefly treated: Uses, market conditions, prices, domestic production, conditions in Canada, South Africa, Russia; problems of the producer.
E. D. ELSTON.

Chrome in 1919. S. H. DOLBEAR. *Eng. Min. Jour.*, 109, pp. 171-2 (1920).—The domestic industry is reviewed in a superficial manner and brief references are made to some of the foreign sources of chrome.
E. D. ELSTON.

Chrome mining in Canada in 1919. R. HARVIE. *Eng. Min. Jour.*, 109, 172 (1920).—The production was limited to the Black Lake and Richmond districts of Quebec and approximates one-half of the production of 1918.
E. D. ELSTON.

Colloidal clay in soap manufacture. F. E. WESTON. *Brit. Clayworker*, 28, 245-46 (1920).—Clay may be brought to such a high colloidal state that it closely resembles soap in its physical behavior and when incorporated with soap increases the lathering and detergent properties, probably due to the formation of a solid solution with the soap. After a certain maximum of alkali is added to soap it is coagulated and loses its lathering power, being similar to clay which is also coagulated by the addition of an excess of alkali. Physically clay and soap are very similar since their surface tensions are lower than that of water, their viscosities greater, they both possess emulsifying properties, both have power of absorbing dirt, grease, etc., and both have detergent properties. A comparison of the surface tension of various mixtures with water by the capillary method gave the following results:

| | At 20° C gr. cm. | At 45° C gr. cm. | At 96° C gr. cm. |
|--|---------------------|---------------------|---------------------|
| Water..... | 0.07205 | 0.06825 | 0.06116 |
| 7.45 g. colloidal clay + 0.125 Na ₂ CO ₃ + 250 cc. water..... | .07013 | .06791 | .06013 |
| 0.5 g. soap in a 100 cc. sol. of water..... | .02422 | .02215 | ... |
| 0.5 g. of mixt. (80 soap and 20 clay) in a 100 cc. sol. of water..... | .02200 | .02062 | ... |

A solution was prepared containing 0.125 gram sodium oleate in 100 cc. sol. of water. Portions were mixed with normal Na₂CO₃ solution, and after shaking the volume of lather (a) and of solution (b) were measured.

| | 10 cc. sodium oleate + 10 cc. $N Na_2CO_3$ soln. | | 10 cc. sodium oleate + 10 cc. $N Na_2CO_3$ soln. + 0.01 gr. colloid clay | |
|------------|---|----------|--|----------|
| | a | b | a | b |
| 1. | 16.0 cc. | 18.0 cc. | 19.0 cc. | 15.2 cc. |
| 2. | 16.0 cc. | 17.8 cc. | 20.7 cc. | 14.8 cc. |
| 3. | 16.3 cc. | 17.2 cc. | 21.6 cc. | 14.9 cc. |
| 4. | 17.0 cc. | 17.0 cc. | 21.6 cc. | 14.9 cc. |

Alkalies in face soap are harmful to the skin whereas clay in soap is not.

H. G. SCHURECHT.

Feldspar in 1919. J. V. LEWIS. *Eng. Min. Jour.*, **109**, 238-9 (1920).

A reduction of 15 to 20% of the 1918 output is expected for 1919, due to existing conditions of labor, shipping, etc. The reduction occurred mainly in Pennsylvania, Maryland, California, and to a lesser extent in North Carolina. The 1919 Canadian production is reported to have suffered a considerable decrease.

E. D. ELSTON.

Mica in 1919. J. V. LEWIS. *Eng. Min. Jour.*, **109**, 237-8 (1920).—Production, imports and exports, and prices are briefly considered and new sources of possible commercial importance are noted as follows: A new biotite deposit in North Carolina, deposits in Guatemala, and several occurrences in Siberia.

E. D. ELSTON.

Silica, an aid in the determination of. S. R. SCHOLES. *Chemist Analyst*, No. 29, pp. 22-23.—In the analysis of silicates, where silica is separated by evaporation with hydrochloric acid, it is not easy to detect the last small particles of silica adhering to the evaporating dish when the evaporated mass is taken up with water and filtered. Methyl orange is very helpful in this operation. Not only is this a suitable indicator to make certain the acidity of the liquid as it evaporates, but as the gelatinous silica separates it becomes strongly colored by the methyl orange. The silica retains its orange dye quite strongly in the subsequent washing. Each particle of silica is readily detected on the evaporating dish, and the analyst may be sure when all the silica has been brought upon the filter. One may thus avoid the necessity of drying the dish to ascertain whether or not silica has been left behind.

A. J. LAMBERT.

Talc and soapstone in 1919. R. B. LADOO. *Eng. Min. Jour.* **109**, 235-7 (1920).—Brief statements concerning the talc industry include the following topics: Uses of talc as a substitute for English clay; as a substitute for graphite, and as a filler; reorganization of the industry; development of domestic sources; prices, production and imports; foreign situation.

E. D. ELSTON.

PATENTS

Heat-insulating material and process of making it. W. H. WINKLEY. U. S. 1,332,370, March 2, 1920. This is a composition very similar to that disclosed in U. S. 1,332,348. However, because of the deliquescence of caustic soda, a mixture of sodium carbonate in the form of soda ash and hydrated lime is substituted therefor. The proportions used are: Infusorial earth 85 parts, gelatinized starch 10 parts, soda ash 5 parts, and hydrated lime 2 parts.

Heat-insulating material and process of making it. R. B. MACDONALD. U. S. 1,332,348, March 2, 1920. A heat-insulating, heat-resisting material is made of 100 parts infusorial or diatomaceous earth, 3 parts gelatinized starch, added to lend sufficient coherence for molding, and 1 part sodium or potassium hydroxide. This material may be used as a mortar or as a paste to be applied to steam boilers or it may be made into blocks and dried at 300° F. It is said to be able to withstand 3000° F.

Kiln. R. C. PURDY. U. S. 1,332,471, March 2, 1920. This is a round downdraft kiln of a modified Lawton type. The hot gases divide at the rear of the fire box, a part rising vertically through the bags as in an ordinary downdraft kiln, and a part passing through radial flues beneath the floor to a center well or bag which rises within the kiln chamber a distance a little less than half the height of the crown above the floor. After passing through the ware the gases pass through apertures into other radial flues beneath the floor and outwardly into individual stacks located within the peripheral wall of the kiln. Improvements have been made in the structure and arrangement of flues beneath the floor.

Tunnel-kiln. G. W. BOORH. U. S. 1,333,099, March 9, 1920. Atmospheric air enters spaces within the walls and crown of the kiln at the end of the cooling zone, passing through these spaces along the length of the kiln at the end of the cooling zone, passing through these spaces along the length of the kiln and down through vertically disposed iron pipes which line the walls of the preheating zone. Ware entering the kiln is thus preheated without coming into contact with products of combustion.

Tunnel kiln, continuous. C. J. KIRK. U. S. 1,332,501, March 2, 1920. This is a twin tunnel muffle kiln, the ware traveling in opposite directions in the two tunnels, thereby effecting a mutual cooling and preheating. The longitudinal partition wall is provided with staggered openings at top and bottom to permit of circulation of air between the two tunnels.

G. E. MIDDLETON.

Refractories

Muffles. *Tonind, Zeit.*, **44**, 168-9 (1920).—The requirements of a muffle are (1) resistance to temp. change, (2) mechanical strength and (3) good conductivity. About 2 parts of grog are used with 1 part of bond clay. For small muffles the size of grain is about 1-2 mm. Sawdust is often added to the body to make it lighter in weight and more resistant to sudden temp. change. Muffles should not be burned too high as this facilitates cracking.

H. G. SCHURECHT.

Graphite in Quebec, Canada. H. P. H. BRUMELL. *Eng. Min. Jour.*, **109**, 548-550 (1920).—Graphite is of widespread occurrence in Quebec, especially in Argenteuil, Labelle, Wright and Pontiac counties where in the Grenville or upper part of the Laurentian series of rocks it occurs as disseminations, in masses and in veins, the first named type of occurrence being the most important.

The Quebec and Alabama graphite may be briefly compared as follows: (1) The Buckingham ore is Archaean in age while the Alabama material is Carboniferous. (2) Genetically, Buckingham graphite is inorganic or elemental. The Alabama graphite is organic and due to alteration of coaly or carbonaceous material contained in the sandstones prior to metamorphism. (3) In Quebec near the eruptives there is an enrichment of graphite while in the Alabama deposits an increase in muscovite occurs without appreciable change in the graphite content. (4) Alabama ore consists almost entirely of soft weathered ore; the Buckingham material is usually tough and hard. (5) Mineralogically they are similar affording "flake graphite." The gangue in the Alabama ore, however, consists almost entirely of very friable quartz with a small amount of sillimanite (?), occasionally mica (either biotite or muscovite), cyanite and tourmaline. The Buckingham material is accompanied by some quartz together with such common minerals as orthoclase, pyroxene, hornblende, sillimanite and occasionally mica (usually biotite), zircon, tourmaline, chondrodite and pyrite. (6) Buckingham graphite is a coarser flake with higher specific gravity than that of Alabama and is in greater favor with crucible manufacturers. The Quebec graphite has a higher specific gravity than Ceylon graphite and in its heat-resisting qualities is practically the equal of the Ceylon material. Methods of concentration are considered and tables are included which show: Specific gravity and refractory values of both domestic and foreign graphite; analyses of graphite from various North American districts and from Ceylon; grade of Buckingham deposits; screen tests on Quebec and Alabama materials.

E. D. ELSTON.

Graphite industry during 1919. B. L. MILLER. *Eng. Min. Jour.*, **109**, 226-227 (1920).—The article is a somewhat generalized review of the industry and deals briefly with the following phases: War demand for graphite crucibles, the development in Alabama, graphite imports limited, preference

of Ceylon material for crucible manufacture, exclusion of graphite in War-Minerals Relief Bill, prices, 1919 production in the United States, Ceylon graphite industry in 1919. E. D. ELSTON.

Magnesite in 1919. W. C. PHALEN. *Eng. Min. Jour.*, **109**, 217-9 (1920).—A general review of the magnesite industry is given. Among the topics briefly treated are the following: Stocks on hand at end of the war, unsettled domestic industry in 1919, industry in the west, effect of car shortage on production, Canadian magnesite industry, tariff legislation, uses of magnesite and quality of the domestic product. E. D. ELSTON.

Graphite industry in Alabama in 1919. W. F. PROUTY. *Eng. Min. Jour.*, **109**, 228 (1920).—Crippling of the industry due to removal of import restrictions on graphite is briefly discussed. E. D. ELSTON.

Glass

Bohemian glass industry. *Chem. Met. Eng.*, **22**, 464 (1920).—The well known glass manufacturing district of Jablonec (Gablonz), in the Republic of Czechoslovakia, alone exported from February 1 to October 31, 1919, products valued at 17,000,000 Czechoslovak crowns, mostly to the United States, France and Italy. Previous to the war, of the 202 glass furnaces in the Austro-Hungarian empire, 162 were in the Czechoslovak domain. Of the total production for 1913, valued at 117,400,000 crowns (the normal value of the Austro-Hungarian crown was 20 cents—United States currency), 105,500,000 crown represented the Czech and Slovak products.

A. J. LAMBERT.

Electrical conductivity of soda-lime glasses. R. AMBRONN. *Ann. der Phys.* (4) **58**, 139-64, 14/2 (1919), 20/8 (1918); *Chem. Zent. Bl.* No. **5**, Bd. **11**, p. 176 (1920).—Previous investigations of conductance in glasses were accompanied with many difficulties because ordinary glasses contain usually from 5 to 8 components and it was impossible to determine quantitatively the relation of conductivity to chemical composition. By utilizing 13 special glasses made by Schott, which consist of only Na_2O , CaO and SiO_2 , the investigator has established the relation of the electrical conductivity of these glasses with their content of Na_2O and CaO to temperature. The relation of the conductivity to temperature is expressed by a simple exponential function with the reciprocal of the absolute temperature as exponent. A glass containing only Na_2O , CaO and SiO_2 shows values differing from zero only when its content of Na and Ca atoms together comprise at least 11 atoms to each 100 atoms of the glass substance. It is noteworthy that we must not consider Na_2 but an Na with a Ca atom. WM. M. CLARK.

Glass and glass making. ESTHER SINGLETON. *The Mentor*, **7**, No. 5.—Like most of the arts, glass making originated with the Egyptians and the

Phoenicians, and was carried by them to the isles of Cyprus and Rhodes, thence to Rome, and from Rome throughout western Europe. In Egypt its use was chiefly decorative, and among archeological remains are glass beads, vases of glass for cosmetics, unguents, and kohl, small pitchers, scarabei or sacred beetles, many of which antedate the Christian era by two thousand years. The Egyptians favored blue in their glassware, of all shades from dark to the famous "Nile blue," mustard and pale buff, pale green, and red in imitation of jasper. The Phoenicians, on the contrary, produced a pure white glass for use in vases, and an opaque glass for beads. Historians agree that glass production was not indigenous to Greece, for it is not until the fifth century, B. C., that we find any mention of it by their writers. Remains are still extant, taken from the Cyprian and Rhodian islands. They are chiefly small bottles, colorless, or of pastel shades, pale green, rose or buff. By the Augustan era the Romans had converted the art of glass making into an industry, and factories for glass manufacturing had sprung up all over the Empire. These factories turned out every conceivable utility and employed every color but ruby, their glass varying from opaque to milky white, mottled, variegated, and opalescent, and extended in its use to include not only bottles but ornaments of many kinds, dice, tiny balls to cool their hands, and once, to please an emperor's fancy, an entire banquet of glass viands. Byzantine and Venetian artists inherited the Roman science, and were welcomed guests in all the courts of Europe. It was a Byzantine artist who constructed the famous Holy Grail, and another who made the not less important "Hedwig Glasses," heavy dark-colored tumblers, cut on a wheel and with figures in high relief. Enameled glass, which was popular throughout the Middle Ages, was particularly the product of the Arabian and Saracen, who had adopted it from the Persians dwelling in Damascus and Aleppo. Over its texture of dull gold gleamed the red, blue, white and green enamel. After Tamerlane captured Damascus, the art was carried to Samarcand where Damascan artists, although in captivity, still continued their craft. Venice was famed for her enameled glass as late as the sixteenth century, when she abandoned enamel for the beauty of colorless, transparent, fairy forms. Modern European countries with their heritage of Roman, Byzantine, Saracenic, and Venetian skill, have accepted and adopted according to their national characteristics. Thus France, while opening her doors to the Venetians, turned their art to the creation of stained glass for her cathedrals. Dutch and Belgians preferred to excel in exquisite engraving of bottles and glasses. German glass blowers strove for and achieved unique forms, and attained also those blue-green shades distinctive of the Rhenish bottles. The glass of Bohemia had a brief popularity during the eighteenth century, then was pushed aside to give way to the English flint glass.

J. VAN DE WATER.

Glass and some of its properties. SIR HERBERT JACKSON. *J. Royal Soc. Arts.*, 68, 134-46 (1920).—Glass is not a solid. Long straight pieces of glass rod or tubing if left unsupported will slowly bend and after some years

will become definitely bowed. Different glasses show varying degrees of bowing, but all change somewhat. Plasticity of a glass is of the greatest importance for sealing-in work with metal wires and also in resistance to sudden temp. changes. Two glasses of the same coeff. of expansion may vary greatly in plasticity. In the case of soft metals like copper and platinum the glass in setting seems able to pull and deform the metal wires so that no great permanent strain is left in the glass, while with hard metals like iron and tungsten such metal flowage is not possible and the resultant strain will crack the glass unless the glass possesses marked plasticity. Glass seems to be a truly vitreous and not a crystalline body. Neither etching nor a tearing of the surface by glue dried thereon reveals any definite evidence of a crystalline structure in a clear vitreous glass. Phosphorescence varies greatly in glasses and is particularly strong in glass for X-ray bulbs. B_2O_3 and Al_2O_3 are well known as retarders of crystallization, but TiO_2 is even more striking in its action as a vitrifying agent. Glasses with Na only as the alkali devitrify much more readily than similar glass with K or mixed alkali. Most opal glasses owe their milkiness to globules in which are no evidences of crystallization. Opal glasses produced by phosphates generally "strike" opal at higher temperatures than those made with fluorides, the compounds formed by the fluorides being more soluble than in the case of the phosphates. In general fluoride opals are better for working than phosphate opals, especially in the denser opals. For merely opalescent glasses phosphates give good results, but with greater concentrations of the opal-forming substance there is a tendency to crystallize. Colored glasses may be divided into two main groups (1) with the coloring matter diffused in small particles, which may be likened to colloidal solutions and (2) with the coloring matter in a state resembling that of solution. There is, however, a gradual gradation through both groups. Typical of those in class (1) are glasses colored by gold, copper and selenium. Quick chilling will with each of these materials, yield a clear colorless glass and the greater the concentration of coloring matter the quicker the chilling necessary to prevent color. On reheating they "strike" colors just as opals do. Gold glasses are discussed at length. Glasses colored or decolorized by manganese may be considered as intermediate between groups (1) and (2). Of group (2) glasses colored by nickel and cobalt may be considered typical. Varying proportions and kind of alkali influence such colors markedly. Used in equivalent amounts the coloring in the presence of potash is strongest, sodium next and lithium least. With cobalt the influence is less marked than with nickel.

C. H. KERR.

Glass grinding and polishing. JAMES WEIR FRENCH. *Sci. Am. Supp.*, 83, 308-310 (1917).—When a metal surface is polished, small scratches and pits become covered over with a continuous surface flow layer, and if this surface layer is removed by etching these scratches are exposed. On etching a polished glass surface, fine scratches appear, and it has been wrongly assumed

that glass behaves like metals. In the workshop two kinds of scratches are recognized; one exhibiting irregular fractures is called a "cut," and the other, having clean, well-defined edges, is called a "sleek." The result of this investigation shows that the surface layer of polished glass has somewhat different properties than the original glass. A cut is a scratch in the original glass and a sleek a scratch in the modified material or surface layer. It is these scratches in the surface layer that reappear on etching. An optical glass surface is produced as follows: When the polishing tool, which frequently consists of a flat layer of pitch on the face of a metal plate, is rubbed on the glass surface, the portion of glass in immediate contact becomes liquefied to a depth of about $1/4000$ th to $1/5000$ th inch, and the molecules rearrange themselves uniformly under surface tension. The polishing medium subdivides, breaks up, and removes the surface layer, thus exposing the underlying material. The process repeats itself, and a perfect surface is obtained only by the removal of material beyond the bottom of the hollows produced in the glass during the earlier smoothing process. Although the action of a soft cloth polisher is fundamentally the same as that of a pitch polisher, the surface of the latter being flat and comparatively unyielding, touches only the top of the ridges and gradually liquefies successive horizontal layers, while the cloth polisher comes in contact with the surface of the hollows and the glass surface has a tendency to retain its original shape. A perfect optical surface cannot be obtained with a cloth polisher. A surface that is not completely polished exhibits what is technically known as "greyness" when the polisher is a pitch one. The greyness is caused by scattered light from the hollows. A cloth polisher will mask this greyness but the pits still remain and the glass is optically imperfect. A block of crown glass having one polished and one smoothed face was heated to a temperature which appears to have been below the softening point of the main body of glass and just above that of the surface layer. The smoothed unpolished surface remained unaltered, whereas the polished surface exhibited a network of grooves, due apparently to softening and contraction of the surface layer, in which there must evidently have been a considerable tension. By measuring the depth of these grooves the thickness of the modified surface layer is obtained. J. L. CRAWFORD.

Glass manufacture and the glass sand industry of Pennsylvania. C. R. FETTKÉ. Topographic and Geologic Survey of Pa., *Rept.* No. 12, (1919).—The first eleven chapters deal with the technical side of glass manufacture. Among the topics considered at length may be mentioned the following: Definition, composition and classification of glass; chemical and physical properties of glass; raw materials; preparation of the batch; consideration of fuel and of pots and furnaces used; processes of fusion, annealing and other processes used in the working of glass. Following these topics is a chapter on the statistics of the glass sand industry of Pennsylvania and several chapters dealing with the glass sands of that state. The distribution of glass sands is considered according to geological formations and also with respect to coun-

ties. Two formations furnish all the glass sand produced in Pennsylvania—in the central part of the state the Oriskany is the horizon while the Pottsville furnishes material in the west. Of these two formations the Oriskany is the most important. Screen tests, sections and analyses are given.

E. D. ELSTON.

Glass manufacture at the end of the war. MORRIS W. TRAVERS. *Jour. Soc. Chem. Ind.*, 38, 388-391.—The results of the war work show that research must be made into the nature of glass, and experimental methods for this must be developed. The difficulties of this research are enhanced by the nature of technical glass which often, if not usually, represents unstable systems, and it is, therefore, unusually difficult to find any close relationship between the composition and properties. Another difficulty which will confront future investigators, as it did those who undertook the research at the beginning of the war, is the paucity of literature on the subject and the unreliability of the literature which does exist. A reasonably perfect resistance glass for chemical glassware has yet to be discovered, and also a furnace capable of working at temperatures high enough to produce lamp-working glass. This glass must be soft and have a low melting point, but it will "plain" only when very strongly heated in the furnace. The chemistry and physics of founding and plaining of glass need further development. A physical constant in lieu of a melting point (perhaps the point of cohesion of two pieces of glass in optical contact) should be determined; as also the viscosity of glasses, information about which would be of use to manufacturers who employ mechanical methods of glass blowing. There is considerable scope for investigations of the materials used in the glass trade. The influence of accidentally-introduced constituents should be known and the possibilities of substituting less expensive materials for those generally used. Methods of handling and treating materials in the glass trade are exceptionally backward and one of the future efforts of research may well be concerned with developing modern methods of manufacture and the utilizing modern machinery in the mechanical parts of glass making. Efficiency methods should be introduced into the plants. Furnace problems, especially those which concern the manufacture and treatment of refractories, are of the utmost importance and the inefficient old-fashioned round furnace should be replaced. England is behind America in the development of mechanical methods of glass making, and in the investigation of the methods already developed. Due to the war, the demand for tubing has increased enormously and the methods of working varied widely among the different glass houses. Statistical information as to these methods would be useful in determining the best processes of gathering, marvering, reheating, etc. Tubes over one inch in diameter should be annealed before issue. Results of the work already done only prove that further knowledge of annealing is necessary. English manufacturers, in order to keep their continental trade, should not fail to return to hand working of flint glass for which, before the war, they were justly noted.

J. VAN DE WATER.

Glass sands in South Africa. DR. PERCY A. WAGNER. *Mining Magazine*, 21, 180-183 (1919).—Research by Wagner upon South African glass sands has been limited to occurrences which may be drawn upon in the near future. Despite lack of investigation, enough is known to warrant the statement that in the Union there are vast quantities of sands suitable for the manufacture of all kinds of glassware except the very finest grades. One occurrence, near Piennaarspoort, in the Magaliesberg, Transvaal, has been used for glass bottles. The sand is pale yellowish white and contains 0.068% heavy minerals. The maximum thickness exposed in the pit is 2 feet 6 inches. It occurs beneath dark gray sandy loam and is composed almost entirely of quartz grains most of which are coated with thin films of ferruginous clayey matter. Additional characteristics are as follows: Concentrate contains 28% magnetic particles; minerals include zircon, rutile, anatase, cyanite, limonite and ilmenite showing alteration to leucoxene; sand is poorly graded and in this respect is inferior to most European and American glass sands. The best material is of the following chemical composition:

| | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | CaO | MgO | Loss on ignition |
|--------------------|------------------|--------------------------------|--------------------------------|------|-------|------------------|
| Unwashed sand..... | 98.98 | 0.57 | 0.10 | None | Trace | 0.31 |
| Washed sand..... | 99.46 | .. | 0.08 | ... | ... | 0.20 |

Extensive deposits of sand suitable for glass making are found in the Moot Valley, especially on the farm Zandfontein, where there is a belt some hundreds of yards wide and at least 2 miles long. While this sand is better graded than the Piennaarspoort material, still it is inferior to the best European and American glass sands. Its chemical and mineralogical composition, however, prove it to be well suited to the manufacture of white bottles and the better grade white glassware. With washing and screening it would probably be good for plate glass. Numerous other occurrences are described in the article and grade analyses and chemical analyses are given. The location and possible uses of the materials are briefly treated. E. D. ELSTON.

Influence of glass on contents of bottles. *Ztschr. f. ges. Kohlensure Ind.* 25, 657-58, 673-74; *Chem. Zentbl. Nr. 4*, Bd. 11, 130 (1920).—Discusses the composition and properties which glass must possess in order to be satisfactory as a container for beverages of all kinds, for example, fruit juices, cider, mineral waters, cordials, alcoholic beverages, in order that the contents shall not be affected in quality or composition. A satisfactory glass contains silica as the main constituent and at least two other metallic oxides, for instance, alkali and lime. The lime content must not be too great, and if it exceeds 20% the glass will be attacked by organic acids and alcohol so that the quality of the beverages from long exposure is deteriorated. If the glass is very finely powdered and exposed to dil. HCl 24 hours it should not lose more than 3% by weight. The suitability of glass can be determined by exposing to vapors of conc. HCl 24 hours when if it shows a white film of chlorides by transmitted light in a room free from dust and NH₃ vapor it is

not suitable for drinking glasses and bottles. A more sensitive method was worked out by Mylius who digests glass 24 hours in an ethereal solution of iodeosin, $C_{20}N_8J_4O_5$. The alkali-eosin formed is insoluble in ether but dissolves in water forming a pinkish color. By comparing with iodeosin alkali sols. of known strength, the degree of attack on the glass surfaces can be quantitatively determined.

WM. M. CLARK.

Standardization of forms of chemical glassware. DR. H. THIENE. Production Engineer of Schott & Gen. Glass Works. *Z. f. ang. Chem.* Nr. 6, 33 Jahrg, 18 (1920).—Detailed discussion of sizes, dimensions and capacity of Jena chemical ware.

WM. M. CLARK.

PATENTS

Blowpipe-operating mechanism for glass-forming apparatus. A. KADOW. U. S. 1,331,772, Feb. 24, 1920. A rotary support carries in circumferential arrangement a number of sets of glass-forming mechanisms, each set comprising a blow-pipe or spindle, a gathering device which withdraws glass from the furnace and delivers it to the spindle, and a finishing mold. The spindle with a blank thereupon is revolved on its longitudinal axis and air blown into the blank. The spindle is then oscillated, the blank then placed in a finishing mold and rotated therein by renewed revolution of the spindle on its longitudinal axis. This renewed revolution of the spindle is more rapid than the first, and in consequence of this rapid movement higher air pressure can be used. Greater uniformity in wall thickness can thus be attained and this is of particular importance in blowing electric light bulbs.

Charging Glass-molds, means for. J. F. RULE. U. S. 1,331,528, Feb. 24 1920. This machine is very similar to the one shown in U. S. 1,331,512, above. Here, however, there are two arms carrying gob-forming cups which are alternatively fed from the same furnace, each arm then carrying its charge to a rotary mold table adjacent to it.

Color-filter for artificial light, glass composition for. M. LUCKIESH and D. A. DEWEY. U. S. 1,331,937, Feb. 24, 1920. This is a glass adapted to be used in connection with artificial light for the purpose of producing an effect similar to that of daylight. The batch formula is as follows: Sand, 1500, soda 535, lime 160, niter 50, arsenic 5, manganese dioxide 3, cupric oxide 5.66, black oxide of cobalt 0.26 pound. This results in a glass which is bluish in color but which has a slight greenish tinge. A very close approximation to various kinds of daylight may be obtained by its use, depending upon the thickness of the glass. Where it is necessary to decrease the heat effect caused by a large proportion of the green element the proportion of black oxide of cobalt may be decreased. When it is desired to approximate skylight a purple glaze having the following batch formula may be applied to the surface of the glass: Vitrifiable carmen (No. 45) 50, vitrifiable blue (No. 245) 2.5, vitrifiable flux (No. 10) 30 grams.

Glass-drawing pot. C. DAY. U. S. 1,333,903, March 16, 1920. This is a double pot construction designed so that while one pot is in a drawing position the other is draining. The pots are mounted, one on each arm of a V, the angle between the arms being 90° . Rotation is about an axis bisecting the angle of the V. When one pot is horizontal and being drawn from, the other is vertical and exposed to the heat of a furnace which melts the residual glass and causes draining. By rotating the V-shaped support about the bisecting axis the position of the pots is reversed.

Glass-feeding apparatus. K. F. PEILER. U. S. 1,332,405, March 2, 1920. Charges of glass are delivered from the delivery spout of a trough by the action of a displacer. This latter is an inverted truncated pyramid of refractory material which moves downwardly and forwardly through the glass during the feeding stroke and then upwardly and backwardly. This motion moves the glass forward in waves or surges which flow over the spout and drop into receptacles positioned to receive them.

Glass-flattening apparatus. G. H. HAHM. U. S. 1,331,916, February 24, 1920. Halves of the usual glass cylinders suspended by one of the longitudinal edges are slowly carried through a heating chamber in which they soften and gradually straighten. When approximately straight they are held against a flat vertical slab and flattened by being rubbed by a succession of horizontal bars carried by two endless chains. Thereafter they are passed into a cooling chamber.

Glass-molding machine. S. E. WINDER and H. C. DAUBENSPECK. U. S. 1,331,792, Feb. 24, 1920. A series of molds are mounted upon a rotary table. Glass is automatically fed to the molds at one point, at another a plunger descends and presses the article to shape (glass tumblers are instanced) and at another the molded articles are ejected by an upward movement of the mold bottom.

Glass-working machine. F. L. O. WADSWORTH. U. S. 1,333,143, March 9, 1920. This machine is one which makes glass articles by a combined pressing and blowing operation. Successive charges are cut from a flowing stream of glass and fed to a blank or parison mold in which a press plunger operates to mold the blank. The articles is then blown to final form in another mold.

Lens-forming process. H. W. HILL. U. S. 1,332,724, March 2, 1920. The stock is heated to a plastic condition and puddled to eliminate bubbles, striae and similar defects. It is then pressed into form while still plastic and the formed lenses annealed before they have entirely cooled from the initial heating.

Lens-molding machine. H. W. HILL. U. S. 1,332,725, March 2, 1920. This is a machine designed to carry out the process of U. S. 1,332,724 and comprises a rotary heating and puddling table, a heated transfer mechanism, a peripheral rotary mold and an annealing chamber.

Transferring molten glass to molds, means for. L. D. SOUBIER. U. S. 1,331,536, Feb. 24, 1920. This machine is similar to the one shown in U. S. 1,331,511, below; instead, however, of having an oscillating chute it is provided with a plurality of such chutes which rotate continuously about a common axis and in synchronism with the mold table.

Transferring glass to molds, apparatus for. R. LA FRANCE. U. S. 1,331,511, Feb. 24, 1920. Gobs of molten glass are fed to an oscillating chute, which swings in synchronism with a continuously rotating mold table during the time the gob is being fed to a moving mold.

Shear mechanism for glass-working machines. H. A. GENEST. U. S. 1,331,847, Feb. 24, 1920. When the glass-shaping machine to which the charges or gathers cut from the supply by the shears are fed is stopped for any reason, such as for repairs or adjustment, it is desirable that the flow of glass continue so that it will not "freeze" around the outlet. It is, however, desirable that the shear mechanism be thrown out of operation at this time. The mechanism of this invention enables the shear blades to be rendered inoperative and again put in operation in proper synchronism with the feeding means.

Sheet-glass drawing apparatus. B. G. BEALOR. U. S. 1,331,796, February 24, 1920. In drawing sheet-glass the sheet has a tendency to narrow as the drawing proceeds. According to this invention two fluid-cooled blocks are at the glass level in the drawing well and by cooling both edges of the sheet obviate the difficulty mentioned above.

Transferring charges of molten glass, apparatus for. J. M. LENTS. U. S. 1,331,512, Feb. 24, 1920. Molten glass is fed to a cup supported by a swinging arm. This arm swings over an adjacent mold on a rotary mold table, deposits a gob therein, swings back for another charge and then over a mold on an adjoining mold table. Thus one gob-forming and transfer mechanism feeds two mold machines.

G. E. MIDDLETON.

Enamels

PATENTS

Enamel for enameling articles of sheet or cast metal. C. MUSIOL. U. S. 1,332,058, Feb. 24, 1920. This is an enamel free of boron, lead, or arsenic compounds. The batch is made of saltpeter, soda, quartz, feldspar, kaolin fluorspar, sodium silico-fluoride cryolite, chiolite, antimony oxide, leuconine, magnesia, clay, tin oxide and appropriate coloring oxides, all in varying proportions.

G. E. MIDDLETON.

White Ware and Porcelain

Cleaning stoneware clays. *Brit. Clayworker*, **28**, 260 (1920).—Attention is called to the fact that inferior stoneware is being produced in England owing to the fact that it is impractical to clean the clays properly. The injurious portions of clay are usually the coarse grains. If these were ground and added to the body in the 100-mesh size no ill effects would result but this would be too costly. If the clay contains large nodules of pyrites, these may be picked out by hand or with an electric magnet; but these methods are unsatisfactory in that they do not remove the finer material. A pug mill with a perforated barrel may be used to separate coarse stones but this does not remove the finer material. A blunderer or wash mill may be used but the great objection is the cost in separating water from clay. If sulphuric acid is used to neutralize the soda, this tends to coarsen the clay and deprive it of its "silky" texture. Settling tanks are too slow. Filter presses are troublesome and costly. Evaporating tanks are costly and unpleasant. The electro-osmose process is too costly. None of the above mentioned methods are as cheap as can be desired, and there is a scope for ingenuity in this direction.

H. G. SCHURECHT.

Electric heaters made of ceramic materials. O. SCHNEIDER. *Keram. Rundschau*, **28**, 99-100 (1920).—Owing to a shortage of metals in Germany during the war, porcelain and majolica have been used successfully as a substitute for metals in the construction of electric stoves. The advantages of ceramic materials over metals are as follows: (1) They are good insulators, (2) they are easily cleaned and not effected by heat, (3) they make better reflectors of heat than metals since they do not absorb the heat very much but reflect it. Electric heaters are healthier than furnace or gas heaters, since they do not change the humidity of the air. Special stoves for heating and cooking are described.

H. G. SCHURECHT.

German pottery factories, the recent visit to some. J. BURTON. *Pottery Gaz.*, **45**, 357-360 (1920).—Representatives of the British Manufacturers' Federation in visiting potteries in the occupied areas of Germany studying their manufacturing methods. German potters pay great attention to the quality of their saggars. All grog is carefully graded and screened in rotary screens. Saggars were made by hand, by hydraulic presses and in some cases round saggars were jigged. In grinding pottery bodies recorders are placed on the mills to indicate the number of revolutions, thus reproducing homogeneous results. In German hard floor tile bodies, feldspar is always added to the body. Flint at the Bonn factory was calcined in special calcining kilns. The preparation of clay dust for tile was usually done in double-edge runners. Hand operated and hydraulic presses were used for tile and in the latter case the upper die was electrically heated, doing away with the use of grease for the lubrication of this die. Corrugated or perforated drying boards were used. Plaster moulds used for casting were always dried completely assembled and never with the respective parts separate.

H. G. SCHURECHT.

Insulators, the destruction of high tension. E. O. MEYER. *Keram. Rund.* 28, 1-2, 11-12 (1920).—In three years' service it was found that out of 977 insulators, 265 were cracked when used on a line in which the voltage amounted from 10-65 K. V. The fact that many insulators on low voltage line (10 K. V.) also show cracks and that many insulators which have been in use 20 years or more showed no cracks would indicate that high voltage and long service are not the causes of failure. It was thought that the pulling of wires during storms might cause the cracking but it was found that this only amounted to 600 kgs., whereas the insulators will stand 2500 kgs., also, cracks formed from pulling of wire are not identical with those observed in the insulators. Two types of insulators were used, one with shoulders (A) and another with no shoulders (B). In model A cracks were abundant; but in model B practically no cracks were found after having been in service. Insulators with sharp corners also showed more cracks than those with rounded corners. Those insulators which show a coarse grained fracture showed less cracks than those with fine-grained fractures. Temp. changes may vary from -20°C in winter to 50°C in summer with sudden chilling to 10°C during a rain. To test the effect of sudden cooling on insulators they were held at 80°C for 10 hours and then cooled to 10°C and then were again heated to 45°C and cooled to 15°C with rain. After one minute distinct cracking was heard and upon examination cracks similar to those found in insulators that had been in service were noticed. Further experimenting showed that the cracks were not due to the effect of temp. changes on the porcelain but to the cement which has three times the coeff. of expansion of the porcelain, which indirectly caused the cracking. It was found that in some cases the cement was not applied evenly one side being 2-3 mm. thicker than the other and in these cases the cracks occurred on the thick side. For the 65 K. V. insulators a thin cement layer of not over 2 mm. should be used on the bottom surface, 3 mm. on the cylindrical portion and not more than 4.5 mm. in the grooved portion. With 45 K. V. insulators the porcelain parts should be made true to dimension so that the cement layer will be uniform and 1.5-2.5 mm. thick.

H. G. SCHURECHT.

Metal technic and ceramics. E. HEINECKE. *Spreehsaal*, 58, 65-6 (1920).—In 1880 a new decoration process was used which at that time proved very popular but at the present time this type of decoration has gone out of style. Upon the body to be decorated the ornament is put with a gold layer which is burned fast in a muffle kiln. The design appears as a dull unpolished layer of gold. The ware is then put into a copper bath where a thick layer of copper is deposited on the gold. The ware is then engraved and decorated by engravers. After engraving the vessel is put into gold bath and is thereby plated and the ware is then ready for market. Chinese ware is now appearing on the market having beautiful metallic decorations which may have been produced by a similar manner, although the exact method seems to be a secret.

H. G. SCHURECHT.

Pottery classes at Camberwell. STAFF ARTICLE. *Pottery Gaz.*, **45**, 354-355 (1920).—In day and evening classes the preparation of bodies, throwing, turning, modelling and mould-making, slip making and casting, glazing, drying and firing, and overglaze and underglaze decoration are taught. It is the object of the school to help the manufacturing potter in modelling and designing wares and in producing wares that shall be related to current household furnishings.

H. G. SCHURECHT.

Stoneware floor tile. E. TUSCHHOFF. *Keram. Runds.*, **28**, 69-70, 79-80 (1920).—White burning, tile must be burned to high temperature making them expensive. A stoneware clay vitrifying at cone 7-8 when used in the place of white clay produces a much cheaper tile although the color is gray instead of white. The following composition is suggested: 45% clay, 42% flint, 12.5% spar and 0.5% magnesite.

H. G. SCHURECHT.

PATENTS

Hollow earthenware parts, method and apparatus for making. C. H. MUCKENHIRN. U. S. 1,332,514, March 2, 1920. In making hollow earthenware such as sanitary ware, a slab of clay is usually laid inside of a mold and pressed by hand to fit the mold, the presser beginning at the bottom and central part of the mold and gradually working outward and upward to assure escape of air. A machine is provided by this invention for carrying out the above-described process with the difference, however, that the slab of clay is applied over a core shaped to conform to the inner face of the article to be molded. A series of rotatable drums having concave pressing surfaces on their faces are arranged in line and operate successively upon the clay slab which passes beneath them mounted upon its core and carried by a conveyor. The first drum presses only the center and bottom of the hollow vessel, the next only those portions nearer the walls, and so on, the last one giving a finishing pressure to the entire surface. This machine is said to be especially well adapted to the pressing of sanitary ware which is made of relatively large pieces that are in turn built up of numerous small parts joined in a whole. The accurate character of the parts produced mechanically makes possible the use of slip in assembling the parts, avoiding the necessity for the soft clay roll joint.

Truck superstruction for sanitary ware. G. BRAIN. U. S. 1,333,381, March 9, 1920. The truck is designed for use in a Dressler tunnel kiln. The ware-supporting superstructure comprises two stories, the upper being substantially enclosed and designed to carry delicate goods and the lower being much more open and intended to carry goods not injured by more intense radiation from the walls of the kiln.

Support for tableware during firing. G. BRAIN. U. S. 1,333,380, March 9, 1920.—These supports are designed for use in muffle kilns. They com-

prise a triangular base plate having columns rising from each apex and on the inner sides of these columns are upwardly disposed recesses designed to hold pegs upon which the ware to be fired is supported. These supports may be superposed.

G. E. MIDDLETON.

Brick and Tile

Red brick manufacture, important factors in. R. W. JONES. *Eng. Min. Jour.*, 109, 490-491 (1920).—That failure in the manufacture of brick may in many cases be attributed to lack of proper geological examination of the prospect, together with lack of thorough chemical and physical examination of many samples of the raw material, is attested to by this brief article which cites examples of failures and states their ultimate cause. E. D. ELSTON.

Standard brick and tile in France. *Brit. Clayworker*, 28, 266 (1920).—Bricks of burned clay whether solid or perforated, and hollow blocks must satisfy the following requirements: (1) They must have a uniform texture, free from laminations; (2) they must conform to within 2 per cent of the standard length and within 3 per cent in thickness; (3) they must not absorb more water than corresponds to 12 per cent of the weight of the brick; (4) they must not be affected by freezing; (5) they must not contain more than 1 per cent of soluble salts; (6) they must have a crushing strength of (a) 200 kilgs. per sq. cm. (2,800 lbs. per sq. in.) for solid first-class brick; (b) 80 kilgs. per sq. cm. (1,120 lbs. per sq. in.) for solid second-class bricks; (c) 50 kilgs. per sq. cm. (700 lbs. per sq. in.) for hollow blocks or perforated bricks; (d) 225 kilgs. per sq. cm. (3,150 lbs. per sq. in.) for pavers.

The tiles should measure 13 to the meter or 22 to the meter, respectively and must fulfil the following requirements: (1) Their texture must be uniform, free from fissures and laminations, and the tiles must ring well; (2) the color must be uniform in first-class tile; (3) the shape must be such that adjacent tiles lie properly on each other; (4) the tiles must not be affected by freezing (5) the tiles must not contain particles of free lime; (6) the tiles must resist a bending weight of 100 kilgs. (220 lbs.).

H. G. SCHURECHT.

PATENTS

Plastic-block-cutting machine. H. R. STRAIGHT. U. S. 1,332,693, March 2, 1920. Plastic material extruded from a die is fed onto a downwardly curving off-bearing belt. The cutting wires are normal to the curvature of this belt. These wires are carried directly by a table which reciprocates transversely of the plastic ribbon and this table in turn is carried by one which moves longitudinally with the extruded material.

G. E. MIDDLETON.

Abrasives

Aluminous abrasive, a new. OTIS HUTCHINS. *Chem. Met. Eng.*, 22, 565 (1920).—A new abrasive material has been perfected by the Carborundum Company. Impurities are present in the new abrasives to about 1.5%, or very much less than in the ordinary type of aluminous abrasive. This has a

bearing on the characteristics of the abrasive grain and the wheel made from it. Its cutting power is increased due to the greater amount of crystallized alumina present. There is less fluxing between the bond and the grain, this resulting in a brittle wheel so necessary for rapid cutting. It also makes it possible, due to the high purity of the grain, to produce wheels of very soft grade. The small amount of impurities allowed to remain in the abrasive is beneficial. It prevents the formation of skeletal crystals and prevents the more or less open and porous structure which is obtained when molten pure alumina is allowed to solidify. The resulting abrasive consequently exhibits a greater toughness and the wheel has a longer life. As the grits commonly used are 20 and finer, almost every individual grit will consist of a fragment broken from a larger crystal of alumina and due to this fact will possess exceptional sharpness. When the alumina crystals in the abrasive are small, a rupture of the grain may mean a tearing away of a few small crystals without fracture. However, when the crystals are large and a rupture occurs in an abrasive grain, it means that a crystal of alumina has been actually fractured and that new sharp cutting points and edges have been produced.

A. J. LAMBERT.

Artificial abrasives, the manufacture of, in the electric furnace. C. J. BROCKBANK. *Jour. Soc. Chem. Ind.*, 39, T, 41-44.—Artificial abrasives require for their production large quantities of electricity, and therefore, the industry has developed in Canada and the United States where such power can be furnished cheaply owing to the enormous water power developments there. Artificial abrasives are of two groups, the silicon carbide and the aluminous. The refractory by-products are also of great value. Natural abrasives were the only efficient ones in use until carborundum (silicon carbide) was discovered by Acheson in 1890. Silicon carbide cannot be used for all classes of grinding, and it was an attempt to make it a universal grinding material which nearly resulted in financial disaster to the Carborundum Company. Its physical properties render it unsuitable for producing the fine smooth finish required in steel grinding. The discovery of carborundum therefore was not entirely responsible for the diminished use of natural abrasives, but the natural deposits were being rapidly exhausted due to the constantly growing demands of industry, and another artificial abrasive made from the aluminous ores was discovered which completed the requirements of the abrasive field. A typical mix used in the commercial production of silicon carbide is 150 pounds petroleum coke, 2520 pounds white sand, 300 pounds sawdust, and 40 pounds salt. A considerable proportion of the mixture remains unconverted, acting merely as a heat-insulating blanket, and will ordinarily be returned to the mixing department to be added to the new materials. Petroleum coke is the form of carbon which has proved most satisfactory for the production of the highest grade silicon carbide, because of the readiness with which it can be converted into graphite by heat. Silicon carbide furnaces are built in sizes varying from 1000 h. p. to 3000 h. p. capacity. A furnace of the larger size will produce approximately 7% more silicon

carbide per unit power input, but this gain is somewhat offset by the fact that the quality of the product is not so good. The furnace transformers used are oil insulated, water-cooled, single phase, and by means of a tap taken off the high-tension side it is possible to obtain any voltage from 160 to 85. The highest voltage is used when the furnace is first cut in, and it should reach full load in less than 3 hours, after which the voltage must be periodically reduced or the furnace will run over-load due to the negative coefficient of the graphite resistor. The side walls must not be taken down for at least 24 hours after the furnace has been disconnected as the product is liable to be injured by oxidation. Subsidiary reactions involving to some degree recrystallization of the product take place after the furnace is disconnected. A typical mix used in the commercial production of the aluminous abrasives is 100 lbs. coke, 1750 lbs. bauxite, 350 lbs. iron borings, smelted in an arc furnace. These furnaces operate at about 100 volts and require 550 k. w. Reduction must not be carried too far, otherwise the abrasive will be too pure and brittle. The power is a small proportion of the total manufacturing cost, and it would, therefore, seem that aluminous abrasives might, quite practicably be manufactured in England, and important developments in this field are to be expected in the near future.

J. VAN DE WATER.

Review of the abrasive materials situation in 1919. F. J. KATZ. *Eng. Min. Jour.*, 109, 231-232 (1920).—This general review includes notes on the following materials: Emery and corundum, garnet, pumice and artificial abrasives. The conditions of these various industries are briefly mentioned.

E. D. ELSTON.

Cement and Lime

PATENTS

Cement. T. A. SHINN. U. S. 1,334,272, March 16, 1920. A hydraulic cement comprising Portland cement and ground slag sand, thoroughly mixed.

Cements and similar products, process for the manufacture of. M. L. BOILLOR AND J. DAUDIGNAC, U. S. 1,332,422, March 2, 1920. The constituent parts of the cement are ground, mixed, fused to molten condition in an electric furnace, and the fused mass run into molds, cooled and ground. Owing to the high temperature obtained the materials completely react on each other to form calcic silicates and aluminates. Hydraulic products having any desired indexes of "hydraulicity," composition, color and quickness of set may be obtained by a proper selection of the raw materials. Examples of some of these raw materials are: Primary rocks such as gneiss and mica-schists; volcanic rocks such as granite, basalt, lava, etc.; silicates of lime and iron; natural silicates of alumina; natural aluminates and bauxite; limestones or any calcium compounds; and blast furnace slags.

Magnesium-oxychloride cement. J. B. SHAW and G. A. BOLE. U. S. 1,333,510, March 9, 1920. The high grade magnesium carbonate heretofore used as the source of the magnesium oxide used in magnesium oxychloride cements is comparatively expensive and has made these cements too costly to compete with Portland cement despite their superiority for many purposes. It has been believed that the calcium carbonate present in impure magnesites caused shrinkage of the cement during setting and consequent cracking. These inventors have discovered, however, that calcium carbonate has no such deleterious effect but that calcium oxide has. They, therefore, employ ordinary dolomite, calcining it with great care in a muffle between 500°C and 815°C . Within this range all the magnesium carbonate is reduced to the oxide but the calcium carbonate remains unchanged. To this calcined mass either a calcium or magnesium chloride solution or a mixture of the two is added.

Plastic mixture and process of making it. M. K. ARMSTRONG. U. S. 1,331,554, Feb. 24, 1920. An electrolyte such as sodium phosphate is added to a clay slip in sufficient amount to precipitate the greater part of the soluble constituents of the clay and at the same time deflocculate it. One-half to $\frac{3}{4}\%$ of some organic colloid such as starch or dextrin is then added. To this is then added powdered calcined gypsum, about 40% of the gypsum to 60% of the slip. The mixture is suitable for uses to which plaster is usually put, especially plaster board.

ACTIVITIES OF THE SOCIETY

Important Actions of Board of Trustees

April 26. It was voted to maintain a booth at the Sixth National Exposition of Chemical Industries, in New York next September. A local committee was appointed as follows: Henry Schmidt, *Chairman*; R. L. Clare, Otto Will, G. H. Brown, W. L. Howat, August Staudt, Leslie Brown, and Chas. F. Binns. The local committee will equip the booth and, in consultation with the manager of the Exposition, will select the time and place for a meeting. The Committee on Coöperation will arrange the program for the meeting and will see to the representation of the Society at the opening general program. The Secretary or the Assistant Secretary will attend all meetings and attend to the registration and the enrollment of new members. Badges will be furnished to all members who register at the booth.

May 5. Inasmuch as the English Ceramic Society has been obliged to cancel their proposed trip to America this summer, it has been voted to hold the regular Summer Meeting in Chicago and vicinity. A meeting of the Chicago members will be called and a local committee chosen forthwith. Detailed plans will be announced as soon as possible.

May 13. It was voted to appoint Dr. E. W. Washburn, with Dr. G. A. Rankin as alternate, as delegate to the Organizing Conference called by the United Engineering Societies, to occur in Washington, D. C., June 3 and 4. The purpose of the Conference is for the "coöperation of engineering and allied technical organizations to further the public welfare wherever technical knowledge and engineering training are involved and to consider matters of common concern to these professions."

MEETING OF THE CHICAGO SECTION

On Friday, May 21st, the Chicago Section of the American Ceramic Society held a business meeting and a short program at the City Club, Chicago, with twenty members in attendance.

The primary purpose of the meeting was to elect a chairman to take charge of the arrangements for the Summer Meeting of the Society. F. B. Ortman was appointed to act as chairman, and he will choose his own committee.

Following the business session, two papers on enamels were presented, as follows: "The Enameling of Cast Iron," L. H. Menne, and "The Preparation of Steel for Enameling," L. G. Whitford. A very enthusiastic and interesting discussion on enamels followed the reading of these papers.

F. L. STEINHOFF, *Secretary*.

NECROLOGY

Mr. George Sweet.—Mr. George Sweet, of Brunswick, Australia, who died on the first Sunday in April, at the age of 75 years, had lived in Victoria since 1867. He was devoted to science, especially geology, and was a member of the Royal Society, the Field Naturalists' Club of Victoria, and of the American Ceramic Society since 1906. For many years he was chairman of the Pottery Manufacturers' Association, and employers' representative on the pottery wages board, and was also a member of the council and chairman of the Pottery Advisory Board of the Brunswick Technical School. He was, from its inception, a representative of the Council of Churches for Victoria.

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EDITORIALS

THE MANUFACTURER AND THE RESEARCH CHEMIST

The research chemist is like the guide and hunter of a camping party of city men. When the meat supply gives out they expect him to supply game. They have no judgment of the training, observation, caution, patience, required for the job, all of which may prove futile—if the game is not there. All his employers know is that he gets his wages and that they want their grub.

Nothing is certain for the hunter and the chemist but the law of chance. And still the former made the front of America's settlement for three hundred years and for three thousand miles. The latter has made the greatest industries of the last fifty years and transformed most smaller ones.

The hunter and the chemist can only be appreciated by their own kind. The public can know nothing but results.

What then is the problem of the manager? He knows what problems he wants solved. But neither he nor the chemist knows in how far they are soluble. The most troublesome may prove ridiculously easy. An apparently slighter one may not be accomplished without upsetting the practice of the industry, which the manager will not face, after the chemist has spent years on the proof.

Let us illustrate. The pigment called "Prussian blue" made in England was superior in quality to that of German makers

There was no trade jealousy and the English colormen invited the Germans to send a practical man to view their process. He went, saw everything and reported that the processes were identical. He added, casually, that the English had very poor equipment, especially in their mills. Liebig went to England on a scientific mission. He had tried his hand on Prussian blue for his countrymen and bearing the problem in mind visited the English works while in the country. When he returned, his former clients asked him if he had gotten any light on English Prussian blue. "Why yes," he said, "I'll show you." At the factory he grabbed up a handful of rusty nails and proceeding to the mill where a batch of pigment was grinding threw them in. The result was brilliant. What, to the practical color-maker, was a poor mill, was to the mind of the chemist something more.

Again, a certain faience factory in America knew they could distance all competitors with true turquoise, lilac, violet and ruby-red enamels. A chemist was engaged and in a reasonable time produced colors over which the directors were jubilant. Success, however, was dependent on short, fire glazing. The manager was hide-bound in refusing to make them, other than in the regular glost-kiln run. The chemist's time and much expense were long incurred in attempting to tie results to an impossible condition, long after it was demonstrated to be chemically inconsistent. The colors have never been produced in America, the manager's "practicalness" was the obstacle.

There is more to the Liebig story than a chemical mind and a simple solution. And in this "more" lies our parable. Liebig had great respect for the man with the poker—traditional practice, epitomizing experience, to the meaning of much of which the college man is commonly blind. Liebig would never attack a problem, with which he had not acquired full practical familiarity from the workmen. Chemical knowledge to him was for illuminating and improving practice, which he was painstaking to learn. The student of chemistry, even when trained in a school of ceramics or any other specialty, is dominated by chemical reasoning and methods and hardly realizes how much is locked up in traditional practice and manipulation. To the student in ceramics, Seger's study of Japanese porcelain should

be impressive, science groping after empiric achievement. Any one prompted to study Chinese porcelain will realize how much is still before us in the same direction!

Our word to the manufacturer then is, if your new chemist asks to spend most of his initial time in shop work, regard it as a mark of intelligence, not of doubt. If your directors begin to get cold feet over his salary and immediate lack of results, and some of them surely will, read Carnegie's address at the opening of the new chemical laboratory of Stevens Institute and fortified by his early faith in the chemist make them stay put.

To the chemist, beginning a new job, we would say, demand the right to work and observe in the shop. Formulate your own questions and initial points of attack. Do not let a pressing defect force you to concentrate first and exclusively on it, simply because it is pressing. The road may be too long and obscure. Minor defects cured will win your spurs and strengthen your backing. Experience gained and incidental observations made often prove a longer lap in reaching the major goal than direct reasoning and experiment.

ORIGINAL PAPERS AND DISCUSSIONS

REPORT OF THE COMMITTEE ON DEFINITION OF THE TERM "CERAMICS"¹

To the American Ceramic Society:

Your Committee on "Definition of the Term Ceramics" submits the following report:

1. Dictionary Definition

As the initial step in its investigation of the topic assigned to it, your Committee brought together the definitions of the terms "ceramics" and "ceramic" as given by a number of English dictionaries. These definitions are reproduced below in Appendix A. From these definitions the following conclusions may be drawn: (1) The word "Ceramics" first appeared in the English language about the middle of the 19th century apparently through adoption from the French (Fr. *Ceramique*). (2) In accordance with modern literary usage, as known to the lexicographers, the term "ceramics" is employed to designate that portion of the plastic arts which embraces the production and decoration of all objects formed by the molding, modeling and baking of *clay*. According to the lexicographers the term is, therefore, practically synonymous with *clay working* or the art of the potter, and there is no indication in any of the dictionary definitions, of a broader significance than this.

2. Technical Usage

As used in modern technology, the term "ceramics" has acquired, at all events in this country, a much wider significance

¹ Received Feb. 27, 1920. Presented to the Society at the Philadelphia meeting and adopted as read.

than that indicated by the dictionary definition. This is illustrated (1) by the range of activities covered by the American Ceramic Society, (2) by the constitution of departments of ceramics in American universities and by the courses of study offered by them, and (3) by the range of material which one finds presented to their readers by American publications in this field.

The duty of this Committee, as conceived by its members, is to determine as far as possible, whether such a wider usage of the term can be justified on etymological grounds or on the grounds of expediency, or both, and on the basis of the results of its investigation to recommend a definition for official adoption by the American Ceramic Society. In undertaking this task the Committee realizes that ultimately it is always usage which will determine the meaning of a word, and that if the American Ceramic Society could bring about a general usage in accord with the broader significance referred to above, this usage would eventually determine the definition of the term regardless of any barbarisms or violations of etymology which such a broader significance might involve. Nevertheless, it is desirable whenever possible, without making too great a sacrifice of convenience, to avoid attempting to establish a definition which clearly constitutes a barbarism or a violation of etymology and historical usage. That this aspect of the matter is one deserving of consideration was also emphasized by the publication, a few years ago, of a paper by Professor Mellor on "The Origin and Meaning of the Term Ceramic" [*Trans. Eng. Ceram. Soc.*, 16, 69 (1916)]. Judging from the tone of this paper, Professor Mellor seemed at that time to feel that the more extended definition of the term could hardly be justified either on etymological grounds or on grounds of custom or expediency, although in the closing sentences of his paper, he suggested that it might be convenient to adopt such a wider definition at some future time. In view of the importance of the points raised by Professor Mellor, it seemed to your Committee that some further study of the etymological evidence could profitably be made, especially since the Committee assumed that, before any final action was taken by the Society the matter would be brought officially before our fellow workers in England and an attempt made to secure international agreement in usage.

3. Etymology of the Term

From the dictionary definitions displayed in Appendix A, it will be seen that three etymologies for the term "ceramics" are suggested. One of these derives the term from the Greek "*keramos*," which is variously defined as "a potter," "the potter's clay," "a piece of pottery," "earthenware," and so forth, the second connects it with the Greek *kera* (wax), doubtless owing to the plasticity exhibited by clay; while the third derives it from the Greek "*keras*," a horn, which was used in early times as a drinking cup. Only the first of these three derivations seems to have been approved generally by the lexicographers (cf. Oldfather, Appendix B), and it will be noted that the meaning which they ascribe to the English term is strictly in accordance with the meaning which they assume to have been possessed by the Greek "*keramos*." In other words, the lexicographers in formulating a definition of the English word, have apparently attempted to do nothing more than simply to translate the definition of the Greek term into English.

Not feeling satisfied with the information which the lexicographers give concerning the etymology of the word, your Committee thought it desirable to have a more careful study made of this aspect of the question, and it accordingly requested Dr. W. A. Oldfather, Professor of Classics in the University of Illinois, to undertake a research upon the etymology and significance of the Greek word from which our term "ceramics" is derived. Professor Oldfather, who has devoted some special attention to the development of the arts and manufactures of Ancient Greece, is qualified to speak with authority on this question, and the Committee has been very fortunate in securing his assistance. Professor Oldfather's findings are contained in his report which is attached hereto as Appendix B.

This report brings out the following facts: (1) The Greek word "*keramos*" from which our term "ceramics" is derived is related to an older Sanskrit root, meaning "to burn," and as used by the Greeks themselves its primary meaning was simply "*burnt stuff*," that is, the *fundamental idea* contained in the word was that of a product obtained through *the action of fire* usually upon

earthy materials. Professor Oldfather shows very clearly, moreover, that it was the process rather than the materials themselves which was the predominant element in the meaning and usage of the term as employed by the Greeks and that only secondarily, if at all, the term also came to designate their chief raw material, that is, clay. While it is probable that the Greeks themselves had no knowledge of the original source of the word, it is evident that their idea of the content of the term was strictly in accordance with the Sanskrit root to which it is related, and that only later by a natural association and extension, was the word ever, if at all, used to designate the raw material of the potters art.

It seems, therefore, clear that in defining the Greek word as signifying *merely* the potter's clay or the potter's art, the lexicographers have failed to sense fully the primary meaning of the term as used by the Greek themselves and that if a fuller translation of the term were given, this translation would not be in any way at variance with the wider significance which the American Ceramic Society is accustomed to attach to the term "ceramics;" that is, no barbarism or violation of original usage will be committed if the term "ceramics" be defined so as to include a much greater variety of industries than merely the clay working industry. Rather such an extended definition would be more in accordance with the origin and historical significance of the term than is the present restricted definition found in the dictionaries.

4. The Ceramic Industries

In general, the usage of the term by the Greeks may be said to involve the two characteristic elements, first and primarily, a product in whose manufacture a high temperature treatment is involved, and second and secondarily, a product customarily manufactured entirely or chiefly from raw materials of an earthy (as distinguished from metallic, organic, and so forth) nature. It is also clear that it is these very elements which also characterize the significance of the term "ceramics" as it has come to be employed by the American Ceramic Society and in accordance therewith we may, therefore, properly define and describe the ceramic industries as those industries which manufacture products by the action of

heat on raw materials, most of which are of an earthy nature, while of the constituents of these raw materials, the chemical element silicon together with its oxide and the compounds thereof (the silicates), occupies a predominant position. In accordance with this definition we may enumerate among the products of the ceramic industries the following:

(1) All kinds of burned clay products, such as stoneware, earthenware, brick, tile, sewer pipe, terra cotta, china, porcelain, and so forth.

(2) Cementing materials, such as Portland cement, dental cements, lime, plaster, and a variety of magnesia and gypsum products whose constituents are of an earthy nature and which, after a preliminary treatment which involves a calcination, acquire the property of "setting" to a greater or less extent, when mixed with the proper liquids.

(3) All varieties of glass and glassware including quartz glass, glazes, enamels and many of the artificial precious stones.

(4) Enameled metal products, where the enamel itself is a ceramic material applied to the metal at high temperature, the metal serving only as a skelton to give the desired form and strength to the glass which it supports.

(5) Refractory articles or materials, either wholly or partially composed of or manufactured from clay, silica (in its various forms), alumina (bauxite), magnesia (magnesite), lime, chromite, asbestos, zirconia, mica, the rare earths, certain carbides and nitrides, and in general any non-metallic product capable of withstanding elevated temperatures. In the case of all products of this class it is evident that a high temperature treatment is fundamental.

(6) Abrasive materials such as carborundum, alundum, and zirconia (and by association, finely divided silica and emery), together with the products manufactured from them by bonding with an earthy material.

(7) Various electrical and thermal insulating products in the manufacture of which earthy materials enter as an important element.

5. Ceramic Chemistry

Of the sciences underlying the ceramic industries, chemistry probably occupies the most important position, and with the

exception of physiological chemistry (? plumbism) and possibly also organic chemistry, practically all of the branches of the science itself find important applications in ceramics. It would, however, be inappropriate to employ the term ceramic chemistry to designate the sum total of chemical facts and laws which are made use of in one way or another in connection with ceramics. Thus, for example, the mere fact that colloid chemistry finds important applications in connection with the ceramic industries would not justify its inclusion under such a term as ceramic chemistry since it properly belongs to the branch of the science known as physical chemistry. A similar situation of course exists in connection with other lines of chemical technology. Thus, for example, in the technology of dye manufacture the branch of chemistry, known as organic chemistry, occupies the foremost place, but important applications of physical chemistry, analytical chemistry, and inorganic chemistry, are also made in this field.

If, therefore, we are to employ the term ceramic chemistry to designate a branch or field of the science it must be upon some other basis than merely the sum total of all chemical facts and laws which may find application in ceramics. It seems to your Committee that there are good reasons for employing the term to designate a branch or field of the science of chemistry and it proposes to define the term ceramic chemistry as *the chemistry of the compounds of silicon* in a somewhat similar way to which the term organic chemistry is employed to designate the chemistry of the compounds of carbon. The element silicon and particularly its oxide and the compounds derived therefrom (the silicates) occupy a characterizingly predominant position in connection with the ceramic industries. Practically all of the products of these industries involve in one way or another the chemistry of this element. It is true that the well trained ceramic chemist must also be familiar with the chemistry of related compounds, such as the other refractory oxides, for example, but a similar statement is also true of the well trained organic chemist who must also know a great deal of chemistry other than the chemistry of the compounds of carbon. In restricting the term ceramic chemistry therefore to the chemistry of the compounds of silicon there is no intention of conveying the impression that

this is all the chemistry the ceramic chemist needs to know, but rather such a definition of the term delimits a self-contained and definite branch of chemistry of primary and fundamental importance to all of the ceramic industries. To the ceramic chemist this branch of chemistry occupies the same position in importance that organic chemistry does to the chemist who is an expert in any of those branches of chemical technology ordinarily classed as the organic industries.

It may appear at first sight that in one respect the above definition is too broad since there are many compounds of silicon (such, for example, as the halides, sulfides, hydrides, and nitrogen compounds, as well as others involving two or more of these classes of elements) which do not at present find any particular application in the ceramic industries. It is obvious that the portion of the chemistry of silicon which deals with silica and the silicates is the most important part of the subject for the ceramic chemist and the point in question here is thus rather one of emphasis than of inclusion or of exclusion.¹

It is thus true that the man who studies the chemistry of silicon from the point of view of ceramics will devote *most* of his time and attention to silica and the silicates, but for a well rounded training he should of course also know something about the other branches of silicon chemistry. The recent attempts to remove iron from ceramic materials and products by treatment with such gases as chlorine and phosgene indicate that some knowledge of the chemistry of the halogen compounds of silicon is not by any means a valueless one for the ceramic chemist. Again, the possible utilization of certain slags in manufacturing cements and other ceramic products also suggests the possible importance of a knowledge of the sulfur compounds of silicon. Similarly the carbides, nitrides, and carboxides obviously are important in connection with the preparation of certain electric furnace products, such as carborundum, monox, siloxicon, and so forth. It seems to your Committee, therefore, entirely appropriate to define the term ceramic chemistry in the above manner.

¹ As is similarly the case in organic chemistry where the well trained organic chemist is expected to have a reasonable degree of familiarity with many organic compounds which do not at present have any industrial importance.

At the present time the chemistry of the compounds of silicon which is included in the training of the average chemist is only the comparatively small amount which he obtains in his general course in inorganic chemistry. In this respect the chemistry of this element occupies a similar position to that occupied by the chemistry of carbon previous to the recognition of organic chemistry as a sufficiently important and self-contained portion of the subject to be recognized as one of the larger branches of the science. It seems to your Committee that the time has come to give a similar recognition to the chemistry of silicon and in the case of those chemists primarily interested in the applications of chemistry to ceramics, to expect that they will devote to the study of this branch the same degree of time and attention that is devoted to organic chemistry by those who expect to make considerable use of that branch of the science. In educational institutions having departments of ceramics, this will naturally mean that the administration of specialized instruction in this branch of chemistry will be under the direction or guidance of this department, since without the presence of a body of students interested primarily in ceramics, there will ordinarily not be any demand for instruction in this field other than the relatively small amount given in general courses in inorganic chemistry.

6. Ceramic Engineering

If it seems desirable to propose here a definition for the term ceramic engineering, it is clear from the foregoing that such a definition would amount to substantially the following: Ceramic Engineering is that branch of engineering which deals with the applications of science to the ceramic industries.

7. Conclusions

In concluding this report on the subject assigned to it, your Committee wishes to urge the importance of the essential unity implied in the usage of the term "ceramic industries" in the sense proposed above. All of the industries named in Section 4 are fundamentally so closely allied to one another that a recognition of this unity, of the nature of the bonds, and of the close co-operation which such unity should bring about is of the greatest

importance to the future development of these industries and to the further progress in the underlying sciences which such development requires. As already pointed out, the chemistry of silicon is common to practically all of these industries. This is also true with respect to the field of high temperature chemistry or pyro-chemistry as it has been called, and it is only through our comparatively recently acquired knowledge of how to produce, control and measure high temperatures in the laboratory, that the modern advances in our knowledge of high temperature processes have been made possible. Moreover, the material "clay" is utilized in one way or another to a greater or less degree in connection with nearly all of the ceramic industries. It seems, therefore, to your Committee that the elements possessed in common are so fundamental in importance that these industries should and will recognize their essential unity and will establish that coöperation of effort which this unity implies and which will prove to be a source of great strength in their future development. It is fortunate indeed that the American Ceramic Society includes all of the classes of industries listed in Section 4 and it is to be regretted that our fellow-workers in England have not thus far seen fit to unite similarly in single technical organization.

To the end that suitable official action be taken with regard to defining the term "ceramic," your Committee makes the following recommendations: (1) That the American Ceramic Society approve tentatively the definitions proposed in this report. (2) That copies of this report be transmitted to the officers of the English Ceramic Society and to those of the English Society of Glass Technology with the request that these societies take such action with regard thereto as seems to them appropriate. (3) That after the receipt of reports of the actions taken by these organizations, the American Ceramic Society then proceed to officially adopt definitions of the terms in question.

While the matter referred to your Committee has to do primarily with the meaning to be attached to an *English* word and consequently only this country and the British Empire are necessarily involved, it should be pointed out that substantially the same term is used in the French (*ceramique*), in the Spanish and Italian

(ceramica), in the Scandinavian, Dutch and to a less degree in the German (keramik) languages also, and that our fellow-workers in some of these countries may be interested in considering the same question with reference to the usage of the term in their languages. This may, however, not be true in the case of Germany, owing to the very extensive and successful propaganda in that country directed toward the abandonment of words of foreign origin. It is, therefore, suggested that copies of the report be sent also to any ceramic societies which may exist in the above named countries, with the exception of Germany.

E. W. WASHBURN

H. RIES

A. L. DAY

APPENDIX A

Definitions of the Words "Ceramic" and "Ceramics"

The Century Dictionary and Cyclopedia, 1911

Ceramic, keramic: (Gr. *keramos*, potters' clay, a piece of pottery, jar, etc.). Of or belonging to pottery or to the fictile arts; pertaining to the manufacture of porcelain, stoneware, earthenware, and terra cotta: as *ceramic* decoration.

Ceramics, keramics: The fictile arts collectively; the art or industry of making jars, vases, etc., from clay which is molded and baked; also, collectively the things so made.

Murray's English Dictionary, 1893

Ceramic, also keramic: (ad. Gr. *keramikos*, of or for pottery, *keramike*, the potter's art, pottery, f. *keramos*, potter's earth, pottery). 1. Of or pertaining to pottery, esp. as an art. (Not in Craig, 1847.) 1850 J. Marryat *Pottery and Porc. Introd.* The Plastic or Ceramic (ed. 1868 Ceramic) Art. 1862 Thornbury *Turner* I 245. About 1775 Mr. Wedgwood began to introduce high art into ceramic manufacture. 1879 Academy 38 Imitations of ancient ceramic work. 2. As sb. in pl. The ceramic art, the art of making pottery. 1859 Gullick and Timbs *Paint.* 30 Writers on ceramics. 1879 Academy 38 (*Article*) Recent Ceramics.

Richardson's New English Dictionary, 1858

(Not given)

American Encyclopedic Dictionary, 1896

Ceramic: (Greek, *keramikos*—pertaining to pottery, *keramos*, a potter). Of or pertaining to pottery, or the art of pottery.

Ceramics: All the varieties of baked or burnt clay. It is distinguished from vitrics, in which silex predominates, the result being glass.

Webster's New International Dictionary, 1918

Ceramic: (Properly pronounced *keramik* only when spelt with k.) (Gr. *Keramos*, earthenware.) Of or pertaining to pottery; relating to the art of making earthenware; as *ceramic* products.

Ceramics: 1. Art of making things of baked clay, as pottery, tiles, etc.
2. Articles formed of clay in whole or in part and baked, as vases, urns, etc.

Jervis' Encyclopedia of Ceramics, 1902

Ceramic: The designation of the potter's art and its production. It is probably derived from a Greek word, "kepac" a horn, which was used in early times as a drinking cup. The son of Bacchus and Ariadne was *Keramos*, the patron of potters, which gives the supposition an air of reality.

New International Encyclopedia, 1902-1914

Ceramic: (Fr. Gr. *keramos*, potter's clay.) A term used to designate the department of plastic art which comprises all objects made of clay, including terra cotta, porcelain, and all other forms of pottery.

The Americana, 1918

Ceramics: The fictile art; the art of the potter. The word ceramics is derived from the Greek *keramos*, the potters clay. The subject "ceramics" can be primarily divided into two basic divisions: (1) the technique and (2) the product.

Encyclopedia Britannica, Eleventh Edition

Ceramics: (Gr. *keramos* earthenware.) A general term for the study of the art of pottery. It is adopted for this purpose both in French and German and thus has its convenience in English as representing an international form of description for a study which owes much to the art experts of all nations, although "ceramic" and "ceramics" do not appear in English as technical terms till the middle of the 19th century.

Funk and Wagnalls' Standard Dictionary, 1917

Ceramic: Of or pertaining to pottery (including porcelain and terra cotta), or its manufacture, fictile art, or ceramics in general. "The ceramic art is the art of manufacturing objects of all sorts, in every kind of clay, and of decorating them by means of painting or modelling, or both." *Adeline Art Dictionary*.

Ceramics: (Gr. *keramikos*, *keramos*, potters' clay.) 1. That department of plastic art which includes the production of all objects formed by molding, modeling, and baking clay, such as vases, bas-reliefs, cornices, cups, articles of porcelain, terra cotta, and pottery in general; fictile art. 2. pl. The objects so made.

Nuttall's Dictionary of Scientific Terms, 1878

Ceramic: (Gr. *keras*, wax), denoting the plastic arts; a term frequently applied to ornamental pottery.

Simmonds' Commercial Dictionary of Trade Products, 1892

Ceramic: A term often applied to ornamental pottery.

A NOTE ON THE ETYMOLOGY OF THE WORD "CERAMIC"^{1,2}

BY WILLIAM A. OLDFATHER³

The word "ceramic" is a transliteration from the Greek adjective *keramikos*, which is derived from *keramos*, a general term designating the product (and perhaps also, although apparently later, if at all), the material of the potter's art. One who produces *keramos* was called a *kerameus*, and from the *kerameis* (plural of *kerameus*), the district in Athens about the Dipylon gate received its name, *Kerameikos*, that is, the "quarter of the potters." *Keramos*, worshipped by the potters at Athens [Philochoros in Harpokration, s. v. *kerameis*, and thence in Suidas, s. v. *keramis*, a son of Dionysos⁴ and Ariadne (Pausanias, 1, 3, 1)], is merely an eponymous hero of the common type among the Greeks, that is an obvious personification from the noun *keramos* itself, and can throw no light either on the origin or proper meaning of that word, which must be determined by the facts of usage and etymology.⁵

Now *keramos* is used of articles made exclusively or ordinarily out of clay by the process of *burning* (e. g., sun-dried bricks⁶ would not be called *keramos* or any other related word).

¹ Received Feb. 27, 1920.

² Constituting "Appendix B" of the Report of the Committee on the Definition of the Term "Ceramics."

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⁴ For a suggestion as to possible reasons for the selection of parentage, see the article *Keramos* in W. Roscher: *Ausführl. Lex. der griech. u. röm. Mythol.*

⁵ The suggestion that *keramos* means "horn" (*keras*), that is originally a "drinking horn" (Larousse: *Grand Dict. Univ.*, s. v. *ceramique*; repeated in the *Nouveau Larousse Illustré*; also Boccardo: *Ency. Ital.*, s. v. *ceramica*) cannot be taken seriously, since there is nothing in the attested usage of either word to favor such a connection, and it is altogether improbable that the first characteristic employment of pottery was in this particular shape or solely for this purpose. The appeal to the word *pot* as derived from Lat. *poto* is useless, because the etymology of this word is not certainly known.

⁶ It might be noted in passing that the verb *kerameuo* was used of brick-making. Pollux, 10, 175.

That the *process* and not the *material* is the most characteristic feature, would seem likely from the further fact of usage that the Greeks often employed other words for "clay," that is, *pēlos* (lit. "mud"), *gē* (lit. "earth"), *argīlos* or *argillos* (lit. "white stuff," "white clay"), *keramis* or *keramitis* or *keramike gē* (lit. "pottery earth"), or simply *keramis* (with the word *gē* perhaps understood),¹ while *keramos* is very rarely, if ever, used in this sense. For not all the instances given by lexicons and commentaries for this meaning of *keramos* stand the test. Thus, to take the earliest instance cited by Stephanus in the *Thesaurus Linguae Graecae*, the phrase "the Attic *keramos*" quoted from Kritias (late 5th century), as preserved in Athenaios, I, 28 C, unquestionably means "pottery;" the sentence which Stephanus quoted from Pollux, 7, 161, is mistranslated, its real meaning, as Joachim Kühn has pointed out, being: "And *keramos* is also used of the whole mass (or class) of vessels made of clay;"² in Plato, *Tim.*, 60 C and D (a sentence too long and difficult to quote here), although *keramos* has very generally been taken to mean "clay," there can be no doubt but that Jowett and Archer-Hinds are right in translating it "pottery" and "earthenware" respectively; in Aristotle, *On Colors*, I, 6, the older Latin versions (*e. g.*, in the Berlin and the Didot editions) which translate *keramos* with *ficile*, "earthenware," are probably right on the general principle of preferring the well established meaning of a word, although "clay" would make as good sense in the context; again, in Aristotle, *Meteorology* iv, 3, 9; 6, 6 and 7, "earthenware" would fit the context perhaps as well as "clay," and is so given not only by the versions mentioned above, but also by so great a specialist in this field, as I. L. Ideler, while in iv, 10, 9, "earthenware" seems to be the only proper meaning, and the word is so rendered in the translations just mentioned. Only in late writers have I found the expressions "waterjars made of *keramos*" (Pausanias—late 2nd cent. A. D.—10, I, 3), "a receptacle made of *keramos*" (Pollux—late 2nd cent.

¹ The expression *parthenios gē* ("virgin earth") used by Clement of Alexandria is a mere rhetorical flourish.

² Stephanus took *hyle*, "mass," in the sense of "material," which is opposed to the sense of the context. The idea which Pollux had was that of Hesychios, s. v. *keramos*, who defines it as "every kind of pottery."

A. D.—6, 14) "vessels made of *keramos*" (Herodian—3rd cent. A. D.—3, 9, 10), and here it is not at all certain that *keramos* denotes "clay," since "earthenware," although the expression may be perhaps a bit illogical, is probably all that was meant.¹

With this usage the results of etymology are in accord, for, disregarding the guesses of Greek lexicographers and the older but inadequate association with *kerannymi*, "I mix," etymologists seem to be agreed now in referring *keramos* to a primitive Indo-European base which means "to burn," as is clear from the cognate *car*—in Sanskrit, *cremo* in Latin, and so forth (e. g., A. Vaniček: *Etymolog. Wörterbuch der lat. Sprache*, 2nd ed., 67; A. Walde: *Lat. etymol. Wörterbuch*, 2nd ed., pp. 109 f.; Leo Meyer: *Handbuch der griech. Etymologie*, 2, p. 361; E. Boisacq: *Dict. etym. de la Langue grecque*, p. 436, and so forth). *Keramos*, accordingly, meant originally only "the burnt stuff." That this was normally clay or some kindred substance is, of course naturally true, but that *keramos* and derived forms were not clearly felt by the Greeks to designate the material *per se* (as we speak of "earthenware"), would seem probable from the readiness with which they applied adjectives to these words, which denote very different materials.

Thus Homer (*Iliad* V, 387) speaks of a "bronze *keramos*"² (jar); Eueugros of Naxos (latter half of the 6th century B. C.) in

¹ As, for example, in Lucian, *Vera Hist.*, 2, 33, "two gates, one iron, the other made out of *keramos*," "brick," or "earthenware" is certainly meant. We might speak of a brick being "made of burnt clay," or a tile being "made of terra cotta," without committing a serious offense, and, although the expression may not be strictly logical, it is in line with the natural development of meanings in the word "make" which leads to the sense "to consist of, or be composed of" [*New English Dict.*, *Make* I, 4]. I should be inclined to justify the expressions just quoted as a natural development of the meaning of *poieo* (make) in Greek similar to that of *make* in English.—I do not claim that *keramos* never means "clay," for, of course, I have not examined all the thousands of instances of the occurrence of this word, and those that are derived from it, but the cases cited by the lexicons for this meaning are not conclusive, and, in any event, that can scarcely have been the primary meaning.

² A scholiast calls this a Cyprian usage, for in that dialect, he says, *keramos* meant "prison." This is obviously only an extension of the meaning "jar" or "pot" (Ebeling, Capelle, Ameis-Hentze, and so forth, *ad loc.*), and Walter Leaf pertinently compares our slang expression "jug" for the same thing.

an inscription preserved by Pausanias, 5, 10, 3, says of his father (or possibly himself) that he was the "first to make *keramos* (here—roofing tile) of stone;" Ptolemy Euergetes (3rd cent. B. C.) in his *Memoirs*, quoted by Athenaios, 6, 229 D, speaks of "silver *keramos*" (table ware) and the famous Kleopatra (1st cent. B. C.), in Athenaios, 6, 229 B, called her tableware "silver and gold *keramos*;" Polybios (2nd cent. B. C.) 10, 27, 10, speaks of "silver *keramides*" (roofing tile); Hegesander (2nd cent. B. C.) in his *Memoirs*, quoted by Athenaios, 14, 621 A, mentions a "leadene *keramis*" (here = a large jar), and Moschion (of uncertain age but probably before the Christian era), in a fragment preserved in Athenaios, 5, 207 A, B and D, speaks three times of "leadene *keramides*;"¹ Pausanias (late 2nd cent. A. D.) 5, 100 3, says of the temple of Zeus at Olympia, "The *keramos* (tile roofing) is not baked earth, but of Pentelic marble cut in the shape of *keramos*;" finally Saint Chrysostom, Homily 7 on the Epistle to the Colossians Ch. 3 (*Patrol.* Vol. 62, Col. 349) denounces the folly of those who "make golden *keramia*" (tableware).

Since *keramos*, therefore, meant properly "burnt stuff," and the Greeks did not restrict it and related words to clay products,² it might, therefore, not inappropriately be applied to related products in whose manufacture a change of physical and chemical properties under the influence of high temperatures is required. In particular the inclusion of an industry like glass-making which developed out of the potter's art and was long closely associated with it, might, by a natural extension of meaning, be included under the technical designation for that art, if, as in this case, there is involved no barbarism, either in usage or etymology. Now glass was no doubt employed first as a glaze for pottery, intended to make vessels tight and durable (H. B. Walters: *History of Ancient Pottery*, 1905, 1, p. 9), and for many centuries

¹ In the first instance "plates" or "roofing" are meant, in the second and third the exact meaning is not so clear, but it is of no consequence for the present argument.

² I do not think it likely that the Greeks were aware that *keramos* meant etymologically "burnt stuff." All I am concerned with is the attempt to show that to their feeling, the word did not mean "clay" primarily, but was applicable to other materials associated for one reason or another with clay products.

glazes were applied to a back-ground of pottery at a period of industrial development so simple as to make it very unlikely that anyone but the potter himself produced the glaze. This state of things existed for a long time in Egypt (W. Froehner: *La Verrerie antique*, p. 9; G. Perrot and C. Chipiez: *Hist. de l' Art, and so forth*, 1, 82off.), and also in the Minoan civilization of Greece where faience ware, glass pastes, and so forth, were abundant for many centuries (Perrot and Chipiez: *op. cit.*, 6, 943ff.; Hall: *Aegean Archaeology*, 82, 105, and so forth), and is perhaps best illustrated in the glazed brick industry of Assyria (Froehner: *op. cit.*, 15), and especially its extraordinary development in ancient Persia (Perrot and Chipiez: *op. cit.*, 5, 816ff., 834ff., 872ff.), where brickmaker and glazier must have been the same person. Indeed it cannot be doubted that glassmaking developed out of pottery manufacture (A. Kisa: *Das Glas im Altertum*, p. 74, H. Blümmer: Article *Glas* in *Pauly-Wiss. Realencyclop.*, 7, 1382), as in some of its forms it has never been separated from it. The thin glazes upon the finest Greek pottery¹ we may be sure were made by the potters themselves, as we have inscriptional evidence for the fact in the case of one early Attic vase which bears the inscription "Oikopheles pottered me" (Walters: *op. cit.*, 1, 379). Only very gradually, from the handling of larger and larger masses of glazes and constant experimentation with them for the production of new effects in color and other qualities, did the manufacture of glass in some forms come to be definitely separated from that of pottery. Although the Greeks had known glass and glazes for centuries, no specific word for the substance in general² is found until early in the fifth century, when Korinna of Thebes used the adjective *hyalinos* (frg. 42, Bergk), and by the end of the century *hyalos* and *hyelos*³ were in common use (Philolaos, Herodotos,

¹ On Greek and Roman glazes see especially H. Blümmer: *Technologie und Terminologie*, and so forth, 2, 88ff., H. B. Walters: *op. cit.*, 1, 118, 127ff., 202ff.; 2, 436f.

² The Homeric *kyanos* was restricted to a dark blue paste only sparingly employed. From the use of the word in later authors it would appear that the word suggested to the Greeks a color rather than a material. The etymology is unknown.

³ Nothing is known of the etymology of *hyalos* (or *hyelos*); the guesses which have been made are not convincing.

Aristophanes, Hippokrates).¹ It is true that the Greeks, as far as I am aware, employed different words for glass, glass-maker, and so forth, and in no case used the same term to include both glass and pottery, but that may be due to the very fragmentary nature of our literary sources (practically all the technological literature has been lost), and to the circumstances that in these sources we find no instance in which the Greeks had occasion to use a comprehensive term to include both the original and the derived industries, as we do frequently under modern industrial conditions. Had they desired such a term, I see no very good reason why they might not have used *keramos*, or some derivative, to denote the complex of allied and derived industries, because of the meaning of the stem and the primacy of the potter's art, both generically and in relative importance.²

Certainly, in view of the numerous instances of extension and contraction of original meaning which modern languages show in the case of words derived from Greek and Latin,³ it would appear almost pedantic to object to the extension of the word "ceramic" to cover a group of industries derived from or essentially allied to the manufacture of clay products, particularly if the technical world has already begun to employ the term extensively in this way. For it is *usus*, as Horace long ago said, *quem penes arbitrium est et ius et norma loquendi*.

¹ The expression "poured stone" (Herodotos, Plato, and so forth) applied properly to opaque glass, was never widely used, and is probably a translation of a foreign, perhaps Egyptian (W. Froehner: *op. cit.*, p. 4) term. Our expression "stone jar" might be compared.

² Very much as *chalkens* (copperworker) was applied to metal workers in general, because of the primacy of work in copper.

³ A journal does not have to appear daily, the physicists have dissected the atom (a plain contradiction in terms); bucolic is no longer restricted to neatherds; botany includes much that is not pasturage; the plumber handles more than lead; the carpenter may make other things than wagons; a horn may be made of tin; a pen of steel, and so forth, and so forth.

A HIGH-TEMPERATURE TRANSVERSE-STRENGTH TEST AS A METHOD OF TESTING SAGGER MIXTURES¹

S. C. LINBARGER AND C. F. GEIGER

In the manufacture of saggors to be sold for use in the various ceramic industries and in the sale of non-plastics for use in saggors it has been necessary to make tests on very many unrelated mixes. For this work it was necessary to devise tests that would tell in a short time the relative values of mixes, for it was not feasible to follow the laborious procedure of making full size saggors and determining their natural life in regular kiln runs. The life, of course, is the important item, and such a test in some instances would have a duration of years.

Large saggors for sanitary ware, and so forth, must withstand at high temperatures the severe transverse strains that often result in sagging bottoms or rupture. Warped saggors often cause complete losses of such low-bond wares as abrasive wheels and of large, heavy ware.

There have been efforts made to establish a compression load test at high temperatures on whole saggors. Theoretically this is an ideal plan, but it fails of its purpose because the result is usually a failure due to mechanical defects of the individual sagger. In this regard it is imperative to distinguish between the strength of the structural sagger and of the sagger mix. The best that can be done is to make the best possible sagger mix as determined by certain standardized tests based upon the requirements of usage; then it is safe to assume that from the best mixes the best saggors can be obtained.

Tests Employed

In connection with the tests on commercial sagger mixes an extensive research was conducted on the sizing of the grog and on the substitution of other non-plastic refractories for the grog.

¹ Received Feb. 27, 1920.

In this latter work more complete tests were made, and these were arranged so as to give mathematical results as far as possible. Such conclusions shall be presented as the completed tests warrant.

The softening points of the clays were determined, and vitrification behavior was ascertained in a general way from briquettes of the individual clays burned to cone 12; otherwise the tests were all limited to the burned trial pieces of sagger mix. Cracking propensities and strength in the dry state were readily revealed on examination.

The following are the tests chosen for standardization: (1) Transverse strength test at 1300°C . (2) Repeated heating tests. In addition, the adsorptions were determined and transverse strength tests of the burned pieces in the cold state were made on a 10,000 pound testing machine. Usually, however, an examination of a burned sagger will tell whether or not the mix is of sufficient strength for handling, and the last test by itself is of little value. The results of the four tests were considered with a view of discovering any correlations that might exist.

We are of the same opinion as J. B. Shaw, who has emphatically stated that for most purposes high temperature load tests should be carried to ultimate failure of the piece tested rather than only to some arbitrary stage of deformation. The transverse strength test at high temperatures was devised in preference to modifying the compression test as described by either Bleining and Brown, Shaw, or Schurecht in the *Transactions and JOURNAL OF THE AMERICAN CERAMIC SOCIETY*, because the former embraces elements of compression, tension, and shear and apparently effects strains very much like those to which saggars are subjected both in handling and in the kilns.

After some preliminary experimenting the green test-piece size for all tests was set at $8 \times 2\frac{1}{2} \times 2$ inches. This gives a very sturdy piece and is much more likely to allow of checking of results than the smaller test pieces usually adopted. The size of trial piece for mixtures of this kind is an important consideration because coarse grog will cause cracking of small pieces, which in themselves are difficult to form with any degree of perfection. The mixes were worked to a good plastic condition and aged in

moist cans for a few days, and the pieces were formed by ramming in a wooden mould. The firing to cone 12 was always done in commercial sagger kilns.

The burned blocks were ground down on disc grinders so that the outer clay skin was removed from the two broad faces, which were at the same time made flat and parallel. The pieces were then approximately $2\frac{3}{8} \times 1\frac{7}{8}$ inches in section. The measurements were in all cases calipered to the nearest sixty-fourth of an inch.

The transverse strength tests at 1300°C were made on a 6-inch span with the load applied in the center. The furnace is very similar in size and design to that recommended by the American Society for Testing Materials for load testing of fire brick. Fig. 1 shows the exterior of the kiln and the arrangement for applying

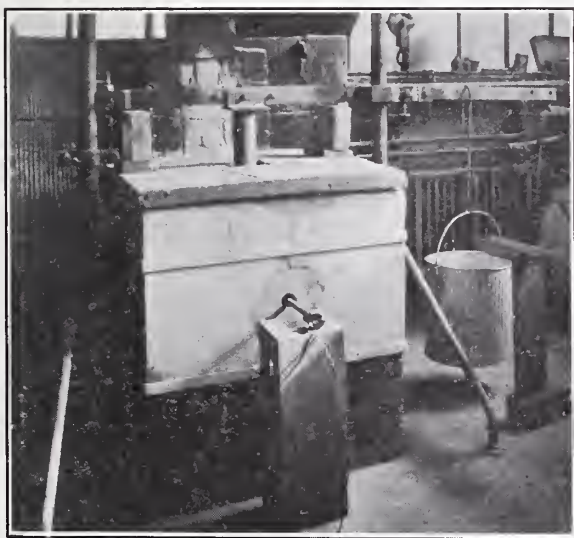


FIG. 1.—Furnace used in determining transverse strength at high temperatures.

the load. The lever arms have a three to one ratio, so that any given load in the pail has a direct effect of three times as much on the test piece.

Fig. 2 is a diagram of the interior furnace setting. From the beam, which is made of two strips of $2\frac{1}{2} \times \frac{3}{8}$ inch bar-iron bolted together and which can be raised and lowered by a bolt and thus be maintained horizontal, the load is transmitted to a tall carbofrax cylinder, *A*, which rests on a carbofrax prism, *B*, which in turn is centered crosswise on the test piece, *D*. The latter is supported on two smaller carbofrax prisms, *E*, which rest on a solid brick setting. The bearing edges of the three prisms are slightly rounded. The test piece is surrounded by a carbofrax ring or muffle, *G*, so that it is not touched by the direct flame. This precaution is very important as will be noted later.

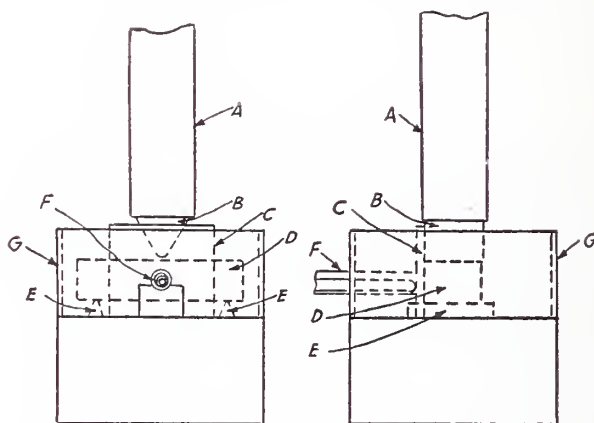


FIG. 2.—Diagram of interior furnace setting.

In contact with the test piece is a carbofrax slab, *C*, about $\frac{3}{4}$ inch thick, which acts as a stop for the heavy cylinder when rupture occurs and prevents damage to thermocouple tubes. Against this slab, which is of very high heat conductivity, is set the end of the thermocouple tube, *F*, containing a platinum couple. In this way the thermocouple is only $\frac{3}{4}$ of an inch from the test piece and in effect is in direct contact with it. The temperatures are taken on a recording potentiometer.

For every test run a definite standard heating curve is drawn on the recorder paper with a template. This curve is followed very closely. The total time of heating up the furnace is 3 hours.

After a holding period of 45 minutes the temperature is still maintained constant and the applying of the load to the test piece is started. This is accomplished by pouring $\frac{1}{4}$ and $\frac{3}{8}$ inch ball bearing culls from a measure that holds just one pound into the V trough, which is about ten feet long. This conveys them in a steady stream to the pail suspended from the lever beam. The load is applied in this manner at the rate of two pounds per minute, which results in an effective increase on the test piece of six pounds per minute. This is continued until rupture occurs. The furnace is then shut off, and the balls are weighed. This weight is multiplied by 3 and added to the effective weight of the lever and the weights of the loading bar and prism.

From this total and the size of the section of the piece, the modulus of rupture in pounds per square inch is calculated from the formula $M = \frac{3Pl}{2bd^2}$, in which P is the breaking load in pounds, l is the length of the span in inches, and b and d are the width and depth, respectively, in inches.

Considerable experimenting was necessary to establish a repeated heating test that could be completed on the best mixes in from three to four weeks and yet would not be too severe on poorer mixes. The question then arose as to when a test piece was to be considered as having failed. It was decided to apply a cold transverse strength test after each heating and to declare a failure when a piece had become so weakened that its modulus of rupture fell below 200 lbs. per square inch. This, of course, is an entirely arbitrary figure and possibly is too low. The number of heatings withstood gives the numerical factor for a given mix under this test.

The first tests were made upon pieces that were set upon the muffle and heated up in the load test firings. This method proved inadequate because the trials were exposed to the direct oil flame and failed in 12 heats, whereas, when muffled and subjected to the same rates of heating and cooling they were apparently unaffected in twenty heats. It would not be possible to set groups of trial pieces so that they could be uniformly exposed to an impinging flame, and hence modification of the test was

necessary. After several variations the following procedure was adopted. The pieces are heated in a muffle furnace to 1250°C in 4 hours; after being held at this temperature for an hour they are quenched in cold water and allowed to remain in the water for a period of five minutes. When they are cold the transverse test is made, and those that withstand it are fired again the next day.

This transverse test is also made with the load-test lever. A heavy plank is laid across the top of the furnace and upon this is set an iron plate, holding two fixed prisms 6 inches apart. The test piece is set upon these and a third iron prism is placed directly under the bearing plate of the lever. The load is then applied by running out a weight on the lever arm, which has been calibrated for the pieces of different size. By trying this on a scale it was found that even if the weight does not move very smoothly the effective weight is never more than it should be as indicated by the position on the lever arm.

Summary of Results

We did not have quite the success that attended Schory's¹ efforts in discriminating between good and bad sagger mixes on the basis of absorption. We find some poor mixes well within the absorption field of long-lived ones.

In the cold state some mixes had moduli as low as 450 and others as high as 3000 lbs. per square inch. At 1200°C the weakest mix tested had a modulus of 70 lbs. and the strongest of 600 lbs. per square inch.

The figures given by Bleininger and Brown² show no uniform relation between hot and cold compressive strength of fire brick. For sagger mixes chosen at random there is likewise no regularity of relation between transverse-strength tests hot and cold, but we have made sagger mixes having very high strengths both hot and cold. The following figures demonstrate the last several points.

Nos. 12 and 67 have practically the same modulus cold yet 12 has only one-third the strength of the other when hot. No. 39

¹ Journal of the American Ceramic Society, 2, 747 (1919).

² Transactions American Ceramic Society, 12.

| No. | Modulus of rupture | |
|-----|--------------------|-----|
| | Cold | Hot |
| 12 | 1130 | 153 |
| 67 | 1180 | 457 |
| 45 | 910 | 405 |
| 70 | 1290 | 558 |
| 39 | 2740 | 494 |

has an extremely high strength cold, more than 100 per cent higher than ordinarily found in very good mixes, and also has a very high strength hot.

Those pieces that have a high modulus of rupture at high temperatures are really stronger than the results show, for their longer loading periods introduce a time element that works against them. By a mathematical calculation it is possible to determine the instantaneous load that will cause rupture or the load necessary to effect a breaking at any given time shorter than the loading period for the individual test piece.

It is not possible to say definitely at this time that the moduli of rupture at 1300° C of sagger mixes are directly proportional to the life of saggars made from these mixes. However, comparisons which are now being made between the actual life of commercial saggars and the results of previous laboratory tests on the mixes used bear out this possibility. Furthermore, these same comparisons demonstrate that almost any sagger mix with a high modulus of rupture at 1300° C (say over 350 lbs. per sq. in. under the conditions described) can be made into a sagger that will give a comparatively long life in actual service.

The apparatus for this test can be made cheaply in any plant shop; and there are few places that do not have a small test furnace to which it may be attached. The equipment is very light and easy to set up and remove. Other methods, such as a small hydraulic jack, may be used for applying the loads. After trial pieces are made a high-temperature transverse-strength test can be run in five hours. This appears to give all the information desired about a sagger mix and to render it unnecessary to make any other tests.

It is essential in the initial firing of the trial pieces that they be subjected to the same burning treatment that will be given

the sagger and that the load test be conducted at a temperature at least as high as that at which the sagger will be used.

THE CARBORUNDUM COMPANY
NIAGARA FALLS, N. Y.

Discussion

MR. M. C. BOOZE.—It is true that the best laboratory test for bat and sagger mixtures is one in which the hot strength is determined. The method of loading, however, is open to debate. I believe that, in the test outlined, the span was too short for the depth of test piece employed so that the influence of a poor bond clay would not be as prominent as desirable. A test which better meets the conditions of use is one in which the bar is uniformly loaded and the amount of deformation is determined. If possible the tests should be made in commercial kilns under working conditions.

MR. EDWARD C. STOVER.—This paper gives a number of practical tests and just how they are made, and should assist in locating some of the aggravating difficulties in this important sagger problem. A few suggestions might still be considered to advantage.

In avoiding troubles generally, the value of being able to reproduce at will the trouble in its various stages is frequently not appreciated. When this knowledge has been thoroughly acquired, how to obviate the particular difficulty in question is more easily and more certainly determined. In most all sagger mixtures is the item of grog (about $33\frac{1}{3}$ per cent or thereabout), and when the proper clay, or mixture, has been obtained, most people would say, "Oh, our grog is all right, we make this ourselves out of our own broken sagger," and it is hard to get them to look there for any of their losses in this line.

The testing appliances and methods described in this important and comprehensive paper should assist in locating and measuring some difficulties, and how to produce them, and thus how to stop producing them.

Here are a few points for consideration, that may suggest a few tests to make, keeping a careful record of the varying results for comparison, and how to duplicate when desired, and how not to duplicate when not desired.

In the first place, are you having kept a record of the life of your various size saggars, showing the average number of fires? And the various kinds of earlier losses? And the causes for said losses? Are you keeping all your ground grog in one place or bin? If so, how are you to know if it is too fine, or too coarse, or evenly distributed in each mixture of the proper degree of fineness? Or are you sub-dividing it into coarse (sending back to be reground that which has proven to be too coarse), medium and fine (rejecting that which has proven to be too fine for maximum strength), and carefully applying in each mixture the proper proportion of coarse, medium and fine grog, approximate sizes of each grade to be determined by these tests, as described?

To prove the value of this suggestion, have made a few test pieces as explained in the paper, using all coarse, a few all medium, and a few using all fine grog. Also a set of trials, using very coarse grog (such as should be reground) and a set with very fine grog (such as should be rejected), and note carefully the result of all these tests by the methods described in the paper, and you will probably be convinced that this is too important a matter to be totally ignored any longer. A microscope or a few microphotos will assist in seeing the results and in locating some difficulties.

With the transverse strength tests, and load tests, as described in the paper, and the uniformities, and thus the duplications, as desired, suggested in this discussion, you should be able not only to locate but to obviate some of your sagger difficulties.

MR. V. S. SCHORY.—The field of this investigation is one of great importance in the ceramic industries and this paper forms a valuable addition to the published data on the subject. In referring to my paper, *J. AM. CERAM. SOC.*, 2, 747 (1919), the authors apparently infer conclusions which are not justified by the data presented. No attempt was made to classify sagger mixtures on the basis of absorption except when the clay content of the sagger mixtures consisted of the same clays combined in different proportions, and then the terms "good" and "bad" can only be used relatively. Undoubtedly, good and poor sagger mixtures can have identical absorptions. However, if the clay content of sagger mixtures consists of one vitrifying clay and one open-burning clay combined in varying proportions there will

be found a short range of compositions which give better saggers than those containing a much less or a much greater proportion of vitrifying clay, and the degree of vitrification occurring in the best mixtures can be determined by an absorption test.

DR. ROBERT B. SOSMAN.—The authors make two assumptions which experience shows to be not always justified in the absence of direct measurements. They assume, first, that the temperature of the test piece is uniform to such a degree that the transverse tests are not affected by the lack of uniformity which always exists in any furnace; second, that the thermoelement, separated by the carbofrax slab and the protecting tube from the test piece, gives the true temperature of the test to the desired degree of accuracy. Both of these assumptions may be, and in this case very likely are, true; but I have never yet found a case where a preliminary exploration did not show much greater temperature gradients than had been supposed to exist. High thermal conductivity, in particular, does not insure uniformity where a large amount of heat is flowing. I believe that the actual distribution should always be determined by a special set of measurements, which need not be elaborate nor take very long to make.

MR. S. J. McDOWELL.—Since reducing atmosphere has a marked effect on fire-clay refractories, I should like to ask if any tests in this paper were carried on under reducing conditions and if so what variation in strength was found?

AUTHOR'S CLOSURE.—In replying to Mr. Booze we may say that saggers that soften in use in kilns are quite evidently of inferior quality and are not suitable for commercial use, even though they can be made from cheap clays. There was no endeavor made to measure the softening; but incidentally this fact is noted in the high temperature load test. The important thing about good sagger mixes, however, is not the softening, but is the lowering of the mechanical strength at the increased temperatures. One set of results can be used to bring out an important point.

| | (1) | (2) | (3) |
|--|-----|-----|-----|
| Per cent of vitrifying clay..... | 40 | 35 | 30 |
| Per cent of open burning clay..... | 10 | 15 | 20 |
| Per cent of grog..... | 50 | 50 | 50 |
| Modules of rupture at 1300° C, lbs. sq. in. | 206 | 222 | 113 |

All of these three mixes were of sufficiently good appearance to promise saggars of about the same quality; mix No. 1 was not too dense and mix No. 3 was not noticeably porous. We see no way in which an arbitrary softening and deformation test is suggested by Mr. Booze would distinguish between these mixes. Over a longer span or under their own or some arbitrary weight less than enough to cause rupture, mix No. 3 would remain unbended while the others would show differing degrees of deformation, and hence No. 3 would be chosen as the superior mix.

One reply to this probably will be that any load that will cause deformation of mixes 1 and 2 will cause rupture of 3. In many instances this might be so, but there undoubtedly are cases where a given load would cause a bending of one piece and would be just sufficiently short of enough to effect rupture of another, and because the second piece did not bend it would be mistaken for a good mix.

A high temperature transverse strength test would give us the ultimate strength of both mixes and at the same time would tell whether or not any deformation occurred, and thus indicate by what variations in composition the mix could be improved.

It is easy to comprehend that if two sagger mixes have the same rate of deterioration of strength in use, the one with the higher initial strength will have the longer life, and the probability is, also, that the stronger one will deteriorate less rapidly than the other.

Most refractory materials have a much lower mechanical strength when hot than when cold, and in very many instances the major cause is not the softening brought about by the vitrifying clay. It is simply that the physical properties are not the same at all temperatures. A high temperature transverse-strength, however, distinguishes between failure due to softening and those due to other weakness, for in the first case the test piece bends before rupture and in the second the piece fails without deformation.

Attempting to conduct the test in commercial kilns, as Mr. Booze suggests, would greatly aggravate the lack of uniformity that Mr. Sosman points out and would render impossible the control of conditions that allows of a fair comparison of results.

In replying to Mr. Stover we may say that, as stated in the contents of the paper, some work was done with reference to the sizing of grog in sagger mixtures, which is known to be of very much importance. In this connection, Mr. Stover might be referred to the work of Mr. F. A. Kirkpatrick, *Transactions American Ceramic Society*, 19, p. 268.

No aim was made in the paper under discussion to tell how to make sagger mixes or what to put into them. As the title clearly brings out all that was attempted was to set forth a quick and effective method for testing such mixes and determining their probable relative values.

Mr. Schory's method is a refinement of the one generally employed. Usually a burned sagger is examined only and if the mix appears to be too dense or too porous, the proportions of the vitrifying and the open burning clays are altered until the desired vitrification is obtained.

In answer to Dr. Sosman, we may say that one preliminary holding period of forty-five minutes and the continued maintenance of the furnace at the same temperature all through the loading period were assumed to make possible some uniformity of temperature. In a small space in a furnace that is being held at a constant temperature it is not unreasonable to expect greater uniformity than if the temperature is being raised or lowered rapidly.

The test piece, moreover, was surrounded by a carbofrax muffle set parallel to and equidistant from its corresponding sides. This entirely prevented the flame from striking the test piece. No such precaution is taken in the standard high temperature compression test of fire brick, but it undoubtedly should be to obviate spot heating.

It was not assumed that the results would not be affected by the lack of uniformity of the temperature of the test pieces; all of the refinements to promote uniformity that it was reasonable to make were made, and as far as there was possibility of control, conditions of any individual test duplicated those of any other. Little more than this can be done in such work.

In answer to the question of Mr. McDowell, we will say that oxidizing conditions were maintained throughout all of the tests

thus far completed. It is unlikely that reducing conditions would effect marked changes in the strengths of mixes containing relatively small amounts of iron or other compounds that are easily altered by reducing gases.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

BEHAVIOR OF FIRE BRICK IN MALLEABLE FURNACE BUNGS^{1,2}

BY H. G. SCHURECHT

The properties necessary for a good malleable furnace brick are evidently not well understood as brick which pass the customary laboratory test, such as the load and softening point test, often fail when used in malleable furnace bungs.

A more thorough study of the relations between the properties of brick and their ability to stand up in bungs has been undertaken by the Bureau of Mines in order to determine the qualifications a brick must possess in order to give long service.

Complete seven-foot arches containing 40 bung brick were tested, as shown in Fig. 1. The number of heats which these

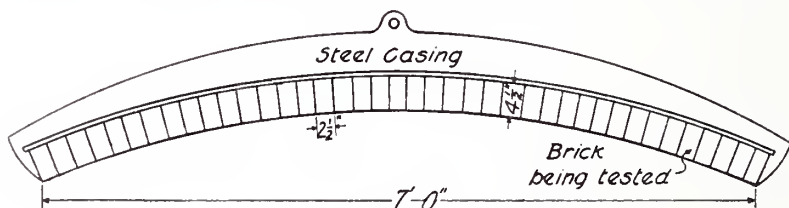


FIG. 1.—Bung of brick as tested.

arches would stand in practice (from 3 to 23 heats, according to the brick) was used as a means of comparing their serviceability. The brick were placed in a definite position over the fire box, where they received the severest heat. The tests were made on a forty-ton malleable furnace operated by the Ohio Malleable Iron Co., Columbus, Ohio. In the laboratory tests the bulk specific gravity, porosity, per cent deformation under load, softening point and chemical analyses were determined, these tests being made in the customary manner. The results are tabulated in table 1.

¹ Received Feb. 27, 1920. Read at the Philadelphia meeting.

² By permission of the Director, U. S. Bureau of Mines.

TABLE I.—TESTS ON FIRE BRICK FOR MALLEABLE FURNACE BUNGS

| No. | Heats | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | CaO | MgO | K ₂ O Na ₂ O | Bulk spec. grav. | % porosity | % deform. with load of 25 lbs. per sq. in. at 1350° C. | Fusion cone | Method of making |
|--------|-------|------------------|--------------------------------|--------------------------------|------|------|---------------------------------------|------------------------|---------------|---|--------------------------------|---------------------|
| 1..... | 18 | 52.93 | 42.69 | 1.98 | 0.33 | 0.38 | 1.55 | 2.04 | 15.50 | 12.2 | 32 | Soft mud |
| 1..... | 18 | 52.20 | 43.42 | 2.18 | .40 | .40 | 1.47 | 2.0 | 15.60 | 15.2 | 30 | Soft mud |
| 3..... | 18 | ... | ... | ... | ... | ... | .. | 1.98 | 15.60 | 6.6 | 32 ¹ / ₂ | Soft mud |
| 4..... | 14 | 52.60 | 43.22 | 2.00 | .40 | .30 | 1.68 | 1.89 | 1.4 | 4.6 | 32 | Soft mud |
| 5..... | 12 | 52.60 | 43.71 | 1.98 | .41 | .30 | 1.68 | 1.94 | 15.90 | 12.8 | 32 | Soft mud |
| 6..... | 3 | 66.22 | 29.83 | 1.12 | .27 | .29 | 1.24 | 2.03 | 13.4 | 11.8 | 30 ¹ / ₂ | Dry press |

Three brick stood up 18 heats. Nos. 1 and 2 show a high alumina content, 42.69 and 43.42 per cent, respectively; also a high bulk specific gravity and low porosity. The chemical analysis of No. 3 has to the present time not been determined, but it also shows a high bulk specific gravity and low porosity. Although these brick, stand up best in practice the resistance of Nos. 1 and 2 to load at high temperatures is not very good and the fusion or deformation test would class No. 2 as a second grade refractory. In Fig. 1 it is seen that the brick are not subjected to heavy load and that one end of the brick is kept cool so the load test and softening point test are not important. Brick No. 4 shows load and fusion tests superior to brick No. 2, yet it does not stand up in practice as well. Its bulk specific gravity is, however, smaller, being 1.89 as compared to 2.01 for No. 2, and this may account for its poorer behavior in practice. The porosity is also comparatively higher, being 19.4 per cent as compared to 15.6 per cent for No. 2 brick. Brick No. 5 also has comparatively a low specific gravity and high porosity.

Brick No. 6 tested poorest in practice. It was made dry press and fired to cone 14, being different in this respect from the other brick which were made soft mud and fired to a lower temperature. It, however, shows a high specific gravity and a low porosity comparing favorably with the best soft mud brick in these respects. Its chemical analysis, is, however, considerably different from those of the other brick. It contains only 28.83 per cent alumina while the other brick contained 42.69-43.71 per cent, which may account for its poor behavior in furnaces. A highly siliceous brick is more readily attacked by basic slags and gases and is also less resistant to spalling than the aluminous brick.

It appears, therefore, that highly aluminous brick with high bulk specific gravity and low porosity are desirable for malleable furnace bungs. These tests are, however, not conclusive as only one test has been made on the brick in bungs, with the exception of No. 6, which has been given three tests. Two or three more checks are now being made on the other brick. The data herein given are therefore, subject to revision on completion of the tests.

In conclusion, the author wishes to acknowledge his indebtedness to Mr. J. M. Kittle, of the Ohio Malleable Iron Co., and Mr. J. M. McDowell, of the Harbison-Walker Co., for their coöperation in this work.

CERAMIC LABORATORIES, U. S. BUREAU OF MINES
MINING EXPERIMENT STATION, COLUMBUS, OHIO

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

RELATIVE ACTION OF ACIDS ON ENAMELS. IV¹

Introduction

There were published in Volume II of the JOURNAL OF THE AMERICAN CERAMIC SOCIETY² results of the preliminary work of the Sub-Committee on Enamels of the Standards Committee. This covered various considerations as to the choice of the proper acid to form the basis of a standard acid test for enamels. It was brought out that an acid procurable in the solid form would have advantages over acids existing in the form of a liquid, assuming such an acid could be found that would be uniform in strength as purchased on the market. Citric and tartaric acids were studied as to their stability and uniformity with the conclusion that either of these from these points of view should make the basis of a satisfactory standard solution.

The additional investigations being reported herewith take the matter up at this point and cover all of the work which has been done up to the present time.

No definite conclusion has been reached and the available data are being presented at this time merely as a matter of general interest in connection with the subject of the action of acids on enamel.

Choice of Acid

The first problem was a choice between citric and tartaric acids. It seemed advisable to obtain the opinion of various food chemists as to the relative merits of these acids for the purpose in mind, and it was the consensus of opinion of those consulted, including such parties as the chemical staff of the H. J. Heinz Company, that citric acid offers a fairer means of testing than does tartaric. Hence it was decided to confine our efforts to the application of citric acid until some conclusion might be reached.

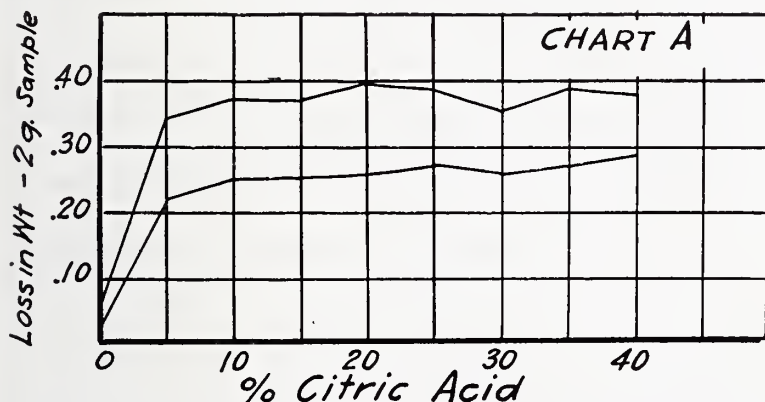
It was desired to make further study of the action of citric acid

¹ Received Feb. 27, 1920.

² "Relative Action of Acids on Enamel, III." *Jour. Am. Ceram. Soc.*, 2, 32.

on enamels, both as to variation in concentration of acid at constant temperatures and variations in temperature at constant strength.

The first investigation was carried on by means of the frit test previously described¹ and using two different fruits with results shown on chart A. From these curves it was noted that there



is a reasonable uniformity of action around 15 per cent acid, small variations of concentration in either direction, making but slight effect in the total activity. Although there are possible irregularities in the curve at higher concentrations, the object in view did not warrant further investigation along this line. It was decided to take 15 per cent as the approximate strength of the desired solution.

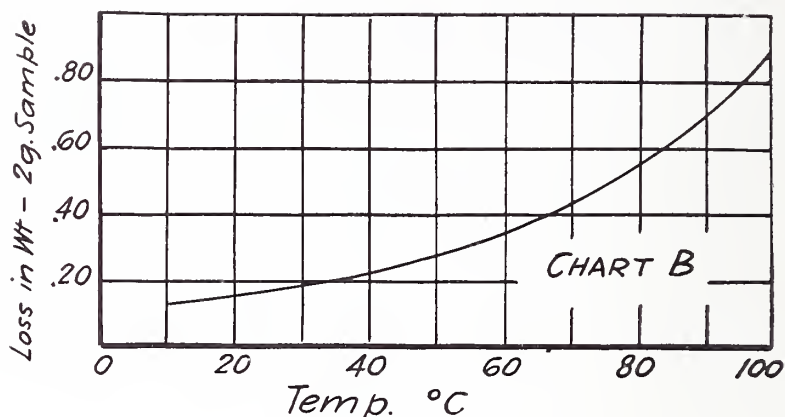
To determine the variations in action due to temperature changes a series of frit tests on a standard frit was made using 15 per cent citric acid by placing the frit and acid in a flask under a reflux condenser and running the test for one hour at each of several temperatures.

The results of these tests are plotted on chart B, which shows the effect of varying temperatures on the activity of citric acid.

From this curve it can be assumed that variations in temperature that might occur in the laboratory at different seasons of the

¹ "Relative Action of Acids on Enamels," *Trans. Am. Ceram. Soc.*, 17, 138.

year ranging from 15 to 35° C would materially effect the results of the standard test, a fact pointing to the necessity of temperature control.



Standard Solution

In making specifications for the strength of a possible solution it seemed feasible to adopt such units as would make use of the English system of weights and measures, eliminating fractional parts. Six ounces of citric acid dissolved in one quart of water makes a solution with the theoretical strength of 15.73 per cent, which was adopted as a standard.

To determine the possible uniformity of solutions made up by different people, four parties were requested to purchase from local drug stores samples of citric acid for analysis in the dry form and also to make up samples of solution in accordance with the above specifications.

Analyses of the various samples thus received are shown in table 1:

TABLE 1

| Source | Dry sample % citric acid | Ash | Solution strength |
|--------------|-----------------------------|------|----------------------|
| Sw..... | 100.14 | 0.02 | 16.06 |
| Ft..... | 100.08 | .08 | 15.19 |
| Dn..... | 100.14 | .03 | 15.75 |
| Ss..... | 100.35 | .03 | 15.74 |
| Average..... | 100.18 | .04 | 15.68 |

It will be noted that the average solution strength was 15.68 per cent compared with the theoretical 15.73 per cent, and that none of the samples varied in a sufficient degree to make an appreciable difference in the action on enamel as indicated on curve A. It is also observed that the amount of ash in the various samples ran very low, only one exceeding the specifications of the U. S. P., 0.05 per cent.

The conclusion from the above tests was that the citric acid obtained from drug stores was sufficiently uniform to make possible the making of a standard solution according to the specifications, within reasonable limits of accuracy. The only possible point was the effect of the ash on gravimetric phases of the test, a matter which will be covered later.

Application to Commercial Ware

Having thus decided upon a tentative standard solution an effort was made to determine the manner in which this solution would effect commercial ware. Several types of sample dishes were used in these tests. In series A three dishes were tested designated as "M," "E-O," and "E-I." "M" was a small white pudding pan furnished by a producer of cooking ware; "E-O" was coated with a relatively high acid resisting enamel used in the manufacture of heavy canning equipment; while "E-I" was coated with a less acid-resisting enamel used in the manufacture of large dairy equipment.

These three dishes were each tested with the standard solution for 24 hours at temperatures ranging from 12 to 20° C, at the end of which times dishes "M" and "E-I" showed a very marked etching and "E-O" no etching.

To determine the possibility of getting consistent gravimetric values from the solution which had been used in such a test, the liquid from the white dish, together with the rinse water used after rubbing the tested area with a rubber tipped stirring rod, was diluted to 500 cc. and two 100 cc. samples were taken, each after a thorough shaking of the flask, and evaporated to dryness and ignited in weighed platinum dishes. The gains in weight were 0.0154 and 0.0141 gram, a variation of 9.2 per cent based on the smaller figure. *

In view of the fact that the first piece of commercial cooking ware tested showed a definite etching under the conditions of the test, it seemed desirable to ascertain whether this particular ware was as resistant as the average cooking ware on the market. Four samples of commercial ware were obtained from local stores and tested in series B. "I" was a white inside and blue mottled outside ware of rather inferior grade, poor in gloss; "SS" was a similar ware of a somewhat better gloss; "CE" was a white pudding pan of good grade; "SE" was a very similar piece of ware. These four dishes were tested under approximately the same conditions as existed in series A with the following results: "I" was badly etched almost chalked;¹ "SS" was badly etched, but not as deeply as "I"; "CE" was slightly etched and "SE" was slightly etched.

As a further test of the possible gravimetric application, series C was run, using dishes "M-3," "M-4," "M-5," all of the same size and from the same batch of first-class ware. After standing 24 hours the dishes showed a uniform etching, and the solutions from each were diluted to 500 cc. as above and ignitions made on the residue from 100 cc. samples. A similar test was made on a blank, using the same amount of the original test solution as had been introduced into each of the dishes. The gravimetric values are shown in table 2, indicating that a reasonable check is possi-

TABLE 2

| Sample | Residue Gr. |
|------------|----------------|
| M-3..... | 0.0088 |
| M-4..... | .0084 |
| M-5..... | .0079 |
| Blank..... | .0006 |

ble on three dishes tested under parallel conditions and that the figure due to the ash in the original acid is relatively insignificant. It might be observed that the actual values are objectionably small, suggesting the advisability of having perhaps a 200 cc. sample rather than a 100 cc.

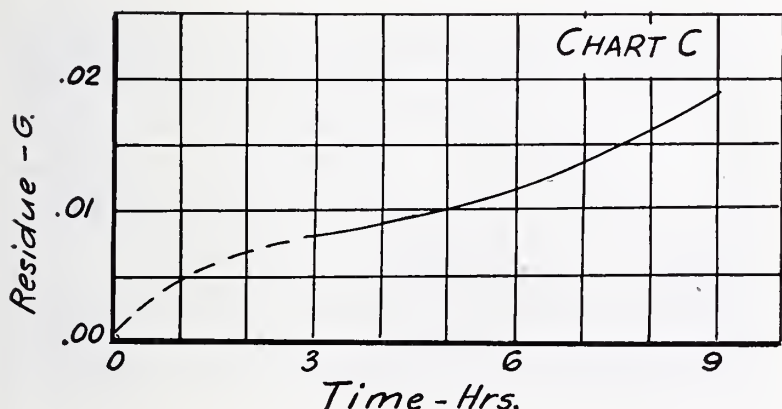
Possible Modifications

Realizing that at least dish "M" in series A and dishes "CE" and "SE" in series B were of first-class quality, it was decided

¹ *Trans. Am. Ceram. Soc.*, **19**, 150.

to consider modifications of this general method of testing, either as to time, temperature or strength of acid, so as to be able to have the better grade wares show no etching.

The first variation attempted was shortening the time in series D, dishes "M-6," "M-7" and "M-8" of uniform shape and quality were each filled with 200 cc. of standard solution. The first was emptied after three hours, the second after six hours, and the third after nine hours. Definite etching was noted in the first with increased etching in the other two. One hundred cc. samples were taken from 500 cc. dilutions giving results indicated in chart C. It will be observed that the values are higher than



would have been expected from tests on the same grade of ware in series C. This was partially due, at least, to the fact that series D was run at a much higher laboratory temperature than series C.

The next modification to be investigated was that of diluting the solution. Series E was run, using dishes "M-9," "M-10," "M-11," "M-12," "M-13," and "M-14," all of the same shape and grade, and the solutions used were $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$ and $\frac{1}{64}$ of the strength of the standard solution, which expressed in percentages, are as follows: 7.88 per cent, 3.94 per cent, 1.97 per cent, 0.95 per cent, 0.49 per cent and 0.25 per cent. As would be expected, the amount of etching dropped off readily as the acid strength had now fallen below the break in the curve

on chart A. Faint etchings could be noted on the dishes which contained the more concentrated acid, but it was very difficult to determine which, if any, dishes showed no etching.

Detection of Etching

This brought up the question of determining when a dish was etched and when it was not etched, a point which it seemed necessary to settle before further experiments with the method of testing could be intelligently interpreted.

Two general schemes were tried on series E. Some finely ground charcoal was rubbed on the enamel on one side of each

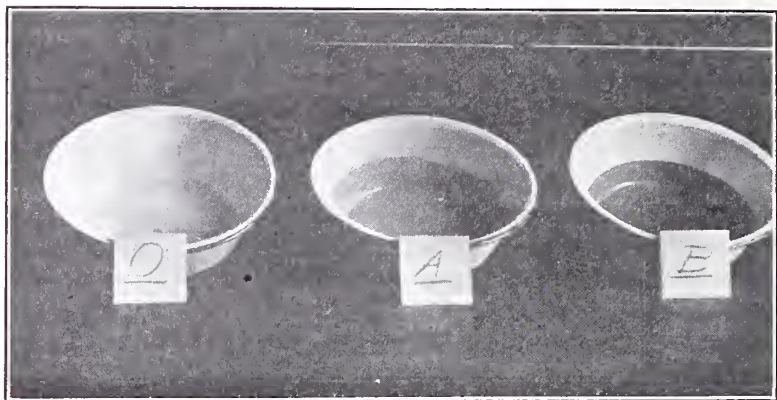


PLATE 1.—Showing the effect of malachite green solution on enameled dishes etched with acid.

dish by means of the finger. This produced in all cases a definite discoloration of the etched portion but no discoloration of the enamel above the liquor line. The relative intensity of this discoloration was not proportional and could be varied by the manner in which the material was rubbed on. This suggested the necessity of some other means of producing a color effect, and a three gram per liter solution of malachite green was used in a preliminary way on the same dishes from series E. A small amount of this solution was placed in each of the dishes and allowed to stand five minutes and the dishes rinsed out. The resulting discoloration of the etched portion seemed to be reasonably

proportional to the strength of the acids which had been in the dishes, and the unetched portion showed no discoloration.

As a more definite test of the same type series F was run on dishes "Fo," "Fa," "Fb." In dish "Fa" 200 cc. of 5 per cent citric acid was placed and in dish "Fb" 200 cc. of 10 per cent citric acid; and the two dishes were allowed to stand for $1\frac{1}{2}$ hours after which these two dishes were emptied and thoroughly washed with hot water, as was also dish "Fo," which was being used as a control and had received no acid treatment. After thoroughly drying the dishes 100 cc. of the malachite green solution was placed in each and allowed to stand for several hours. The solution was removed and the dishes rinsed with hot water and dried, after which "Fo" had no discoloration, "Fa" a marked discoloration and "Fb" a very deep discoloration. These are shown in plate I.

ELYRIA ENAMELED PRODUCTS CO.
ELYRIA, OHIO

Discussion

MR. J. B. SHAW.—This paper, while only a report of progress, represents a very large amount of carefully executed experimental work and discloses very material progress in arriving at the desired result. The author has obviously kept in mind and given due consideration to the fact that any test adopted must not be prejudicial to the best interests of the manufacturers of enameled iron ware. At the same time it is quite obvious that a test to be of any value must have within it the possibility of classifying enameled ware as regards its ability to resist corrosion by solvents. This is essential not only from the standpoint of the public but also of the manufacturer. There is no hope for any material improvement in this class of ware until the manufacturer adopts the practice of studying the quality of his ware and taking steps to improve it wherein it is weak. In order for him to be able to distinguish a good quality from a poor one, some such test as is here recommended is necessary. It would seem that the manufacturers should take up this work and profit by the results demonstrated in this paper.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the editor.

MAGNESITE REFRACTORIES

J. SPOTTS McDOWELL AND RAYMOND M. HOWE

Errata

Page 187, line 5 from top, change "Loeben" to Leoben."

Page 194, line 6 below table, change " $7\text{MgO} \cdot \text{CO}_3$ " to " $7\text{MgO} \cdot \text{CO}_2$."

Page 195, line 12, change "crystalline magnesia" to "crystalline magnesite."

Page 196, lines 4 and 5 from top, change "Semmering, (Eichberg) Veitsch, Biretenau, Trieben, Redenthein (Minstatt) and Dientin (Salzburg)" to "Semmering (Eichberg), Veitsch, Breitenau, Trieben, Radenthein (Millstatt), and Dienten (Salzburg)."

Page 201, line 4 from top, insert the words "in the state" after the word "annually."

Page 216, line 9 from top, omit the words "and shown graphically in sketch 2."

Page 219, line 3 from top, change "effected" to "affected."

Page 224, Figure 2. A straight line should be plotted from 445°C to 830°C , showing a constant conductivity of 0.0135.

Page 225, line 12 from top, change " $\frac{K^\circ}{1000^\circ} =$ " to "Between the

limits of 0° and 1000° , $K =$ "

Page 225, line 9, change "between 0° and 1000°C of 0.100" to "between 0° and 1000°C of 0.0100."

Page 225, line 12, change " $\frac{K^\circ}{1000^\circ} = 0.0124$ " to " $K_{1000^\circ}^{0^\circ} = 0.0124$, etc."

Page 225, line 20 from top, change " 0.04379^t " to " 0.04379 t. "

Page 229, line 6 under Part VI, insert the word "the" between the words "higher" and "temperature."

Page 231, line 13 from top, change "refractions" to "refraction."

Page 235, table of Analysis, change " MgFe " to " $\text{Mg} : \text{Fe}$."

NOTE ON PORCELAIN GLASS POT MIXTURES^{1,2}

BY D. H. FULLER

The use of porcelain pot mixtures in this laboratory made it desirable to know the physical properties of these materials, with reference to their drying shrinkage and porosity upon firing to a series of temperatures, mechanical strength in the fired state, resistance to load conditions and their softening point. Such data are important for checking up the properties of the body produced, as a matter of record and for the determination of the proper pre-firing or arching temperature.

It was also thought desirable to study a number of such compositions varying principally with reference to the sizing of the grog, for which whiteware bisque was invariably employed and with reference to the presence or absence of feldspar.

The compositions of the body mixtures are given in table 1. It will be observed that the amount of grog dust was kept down to a

TABLE 1—BODY COMPOSITIONS

| | Body No. | | | | | | |
|-----------------------|----------|-------|-------|-------|-------|-------|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| | % | % | % | % | % | % | % |
| Feldspar..... | 6.50 | 0.00 | 0.00 | 6.50 | 6.50 | 6.00 | 6.00 |
| Ky. Ball No. 4..... | 11.00 | 11.00 | 14.25 | 11.00 | 11.00 | 10.00 | 10.00 |
| Tenn. Ball No. 5..... | 11.00 | 11.00 | 14.25 | 11.00 | 11.00 | 10.00 | 10.00 |
| N. C. kaolin..... | 11.75 | 18.25 | 11.75 | 11.75 | 11.75 | 12.50 | 12.50 |
| Del. kaolin..... | 5.87 | 5.87 | 5.87 | 5.87 | 5.87 | 4.50 | 4.50 |
| Ga. kaolin..... | 5.87 | 5.87 | 5.87 | 5.87 | 5.87 | 4.50 | 4.50 |
| Grog 10-20 mesh..... | 16.80 | 14.40 | 14.40 | .00 | 38.40 | 18.40 | 15.80 |
| Grog 20-40 mesh..... | 19.20 | 19.20 | 19.20 | 43.20 | .00 | 23.60 | 21.00 |
| Grog 40-80 mesh..... | 9.60 | 12.00 | 12.00 | .00 | 4.80 | 10.50 | 8.90 |
| Grog 80 dust..... | 2.40 | 2.40 | 2.40 | 4.80 | 4.80 | | 6.80 |

low figure, a condition made necessary by the quick cooling of the glass pots in use. The results of the physical tests are compiled in table II. A description of the tests is unnecessary since they have been discussed amply in the literature. It might be

¹ Received Feb. 27, 1920.

² By permission of the Director, Bureau of Standards.

stated, however, that the load test was carried to a maximum temperature of 1350°C and the pressure maintained was 50 pounds per square inch. The specimens for this test were fired to cone 15. The transverse strength of the fired bodies was upon bars previously burned to cone 15.

TABLE 2—RESULTS OF PHYSICAL TESTS

| No. | Water content in plastic state Per cent | Drying shrinkage in terms of dry vol. Per cent | Modulus of rupture in dried state, lbs. per sq. in. | Modulus of rupture fired to cone 15 lbs. per sq. in. | Contraction in load test, per cent of original length | Fusion point Cones |
|-----|--|---|---|--|---|-----------------------|
| 1.. | 19.43 | 5.39 | 298 | 1976 | 1.4 | 31 |
| 2.. | 21.82 | 7.54 | 269 | 2095 | 0.24 | 31 |
| 3.. | 21.82 | 7.68 | 260 | 1838 | 0.12 | 32 |
| 4.. | 21.41 | 7.08 | 263 | 2244 | 0.29 | 31 |
| 5.. | 20.23 | 6.67 | 155 | 1572 | 0.02 | 32 |
| 6.. | 19.66 | 6.31 | 213 | 1998 | 0.06 | 31 |
| 7.. | 19.83 | 7.22 | 250 | 2299 | 0.12 | 31 |

Discussion of Results.—It will be noted that the water content and the drying shrinkage show no marked differences, and that the strength in the dry state is greatest when the content of coarse grog, 10–20 mesh, is relatively low and the material sized between the 20 and 80-mesh sieve higher. Undoubtedly the presence of larger amounts of finer dust would have resulted in greater strength in the dried state. Practically the same statement holds for the transverse strength of the bodies fired to cone 15. From the load tests results it is apparent that these bodies resist pressure conditions under furnace conditions very satisfactorily indeed, due principally to the high silica content of the whiteware bisque grog. The relatively large contraction of body No. 1 cannot be explained from the composition but is perhaps due to a lower degree of burning. The fusion points of the porcelain materials are practically of the same magnitude, cones 31–32.

Firing Behavior.—Briquettes of the seven bodies were made and fired to 8 temperatures, from cones 1 to 15, inclusive, maintaining as closely as possible a steady temperature increase of 20°C per hour. The usual determinations of the volume shrinkage, expressed in terms of the dry volume and of the porosity were made.

The results of this work are compiled in table 3. From the values obtained it is noted that the general behavior of these bodies in firing is practically the same. The most rapid rate of vitrification takes place between cones 11 and 13. The densest body at the latter temperature is No. 7, though No. 1 is very close

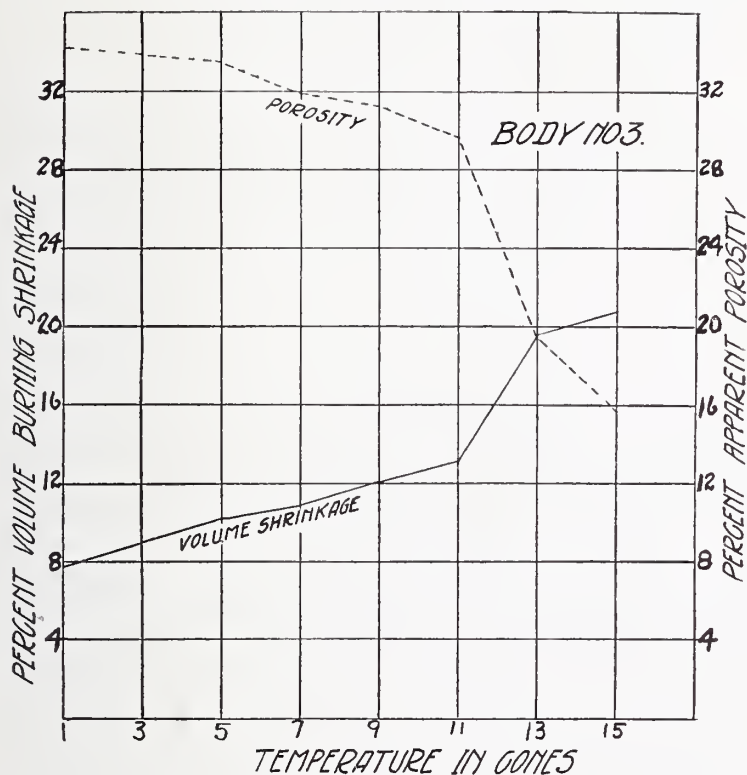


FIG. 1.

to it. The most open structure is shown by No. 2. At cone 15 the minimum porosity is again shown by No. 7, followed closely by Nos. 1 and 6. That lower porosities have not been reached is evidently due to the comparatively coarse grog employed, a condition made necessary by the treatment of the pots which were exposed to an air blast, immediately after the finish of the stirring. Pots practically completely vitrified, obtained through

the use of fine bisque were apt to crack in the cooling. It is evident, however, that the pre-firing of pots of this type must be carried at least to the temperature corresponding to cone 15. The higher porosities of bodies Nos. 2 and 3 are evidently due to the absence of feldspar and in No. 5 to the use of a coarse grog mixture.

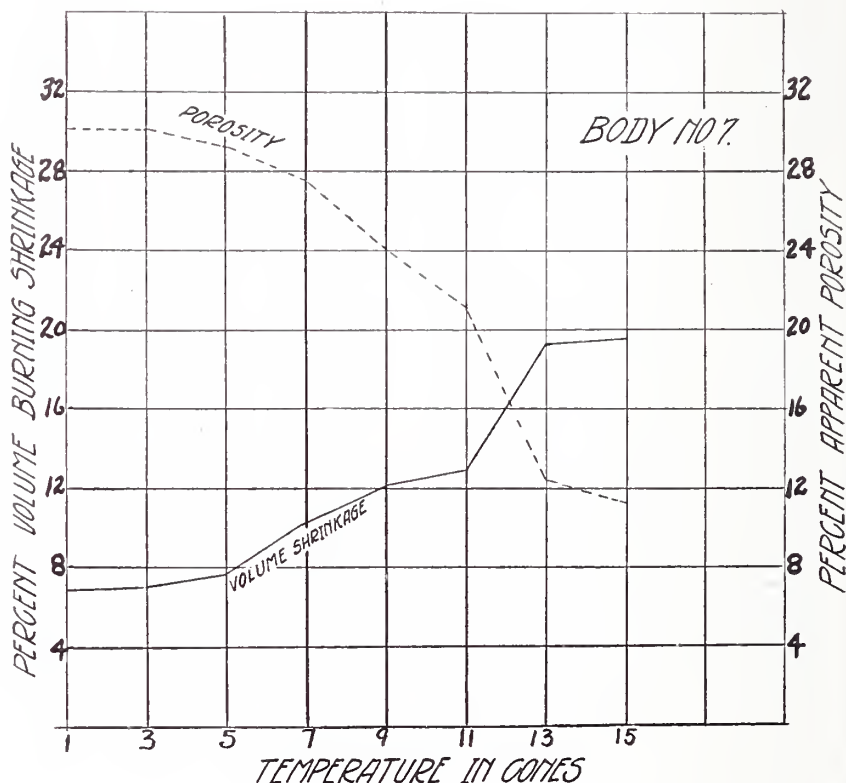


FIG. 2.

The volume shrinkage of the different bodies at 1342°C vary from 15.57 to 22.32%, the lowest value being again that of the coarsest grog combination. The typical firing behavior of these porcelain pot compositions is shown graphically in the diagrams of Figs. 1 and 2.

It would seem from the results obtained that an important factor in regulating the structure of such bodies is to be looked for in the sizing of the bisque grog. Coarser calcine will retard vitrification and result in a more open texture white fine material

TABLE 3—RESULTS OF FIRING TESTS

| No. | Cone 1, 1090° C | | Cone 3, 1100° C | | Cone 5, 1164° C | | Cone 7, 1180° C | |
|--------|-----------------------|-------------------|-----------------------|-------------------|-----------------------|-------------------|-----------------------|-------------------|
| | Vol. shrink. Per cent | Porosity Per cent | Vol. shrink. Per cent | Porosity Per cent | Vol. shrink. Per cent | Porosity Per cent | Vol. shrink. Per cent | Porosity Per cent |
| 1..... | 7.24 | 31.18 | 7.40 | 30.47 | 8.69 | 30.13 | 10.01 | 27.78 |
| 2..... | 7.48 | 34.58 | 7.42 | 33.22 | 8.02 | 33.15 | 8.60 | 32.33 |
| 3..... | 7.78 | 34.23 | 8.90 | 33.90 | 10.17 | 33.48 | 10.80 | 31.97 |
| 4..... | 7.88 | 33.17 | 8.40 | 32.78 | 9.35 | 31.58 | 11.22 | 30.52 |
| 5..... | 7.03 | 31.03 | 8.07 | 30.90 | 8.68 | 30.76 | 10.37 | 29.55 |
| 6..... | 5.65 | 31.77 | 7.28 | 31.47 | 8.92 | 30.60 | 10.72 | 28.67 |
| 7..... | 6.93 | 30.17 | 7.05 | 30.10 | 7.65 | 29.30 | 10.30 | 27.52 |
| No. | Cone 9, 1203° C | | Cone 11, 1244° C | | Cone 13, 1312° C | | Cone 15, 1343° C | |
| | Vol. shrink. Per cent | Porosity Per cent | Vol. shrink. Per cent | Porosity Per cent | Vol. shrink. Per cent | Porosity Per cent | Vol. shrink. Per cent | Porosity Per cent |
| 1..... | 12.18 | 25.92 | 14.13 | 23.62 | 19.53 | 13.78 | 20.17 | 11.83 |
| 2..... | 10.13 | 31.33 | 11.95 | 29.47 | 18.45 | 20.50 | 20.75 | 16.07 |
| 3..... | 12.05 | 31.25 | 13.05 | 29.68 | 19.62 | 19.57 | 20.73 | 15.73 |
| 4..... | 13.82 | 27.73 | 15.57 | 26.47 | 21.07 | 16.72 | 22.32 | 12.83 |
| 5..... | 10.70 | 26.68 | 11.83 | 24.58 | 15.22 | 16.85 | 15.57 | 15.18 |
| 6..... | 12.25 | 26.65 | 14.70 | 24.00 | 20.43 | 15.27 | 20.62 | 11.47 |
| 7..... | 12.18 | 24.07 | 12.95 | 23.08 | 19.32 | 12.42 | 19.55 | 11.33 |

will promote the vitrifying process and yield a denser body. This factor appears to be as effective as the addition or elimination of feldspar. It is evident that in this case we are dealing with a grog tending itself to vitrify at higher temperatures and which develops this action in proportion to its fineness.

The second important factor in governing the state of vitrification is the addition of feldspar which is more effective the finer the bisque grog, and *vice versa*. For obvious reasons there is a definite limit of feldspar content which can not be exceeded without impairing the rigidity of the pots at the higher melting temperatures, around 1450° C, and this seems to be at about 8 per cent. For the purpose for which these pot bodies have been employed the compositions corresponding to Nos. 1, 6 and 7 would appear to be most satisfactory, the last one having perhaps the most desirable structure.

Discussion

MR. A. F. GORTON.—Although the paper deals with pot compositions of the porcelain type and of coarser texture than ordinary commercial pot bodies, I believe that the results obtained should be of great value to all pot manufacturers. Mr. Fuller has selected those physical properties for his tests which are of greatest importance in estimating the value of pot materials, and the results, on the whole, conform very closely to what might be expected from consideration of the composition of the seven bodies.

I would call attention particularly to the load test and to the effect of the sizing of the grog. Those who have used the warp-age test as a means of judging the tendency of pot walls to bulge at high temperatures will, I think, agree that the test is of dubious value, except in a purely comparative way, because it is difficult to standardize testing conditions, and the distortion itself does not correspond exactly to actual conditions. If one considers the hydrostatic pressure of the glass inside the pot, and the pressure due to the weight of the walls and crown above the level in question (which is, say, six inches above the bottom, inside) then it appears that the former quantity is numerically about 1.5 to 2 pounds per square inch, and the latter is from 3 to 5 pounds per square inch, depending on the thickness of wall at that level. Consequently the greater distorting force is that due to the supported weight of clay. Hence the load test may logically be employed, and it seems that it would be better to perform the load test at a temperature higher than 1350°C , also under a smaller load than 40 pounds per square inch.

Mr. Fuller has well brought out the effect of the size of grog upon the modulus of rupture, porosity, and so forth, and I wish that this matter were more deeply appreciated by pot manufacturers, as I believe there is more to be gained by regulating the proportions of fine and coarse grog and the elimination of dust, than by an anxious search for some clay or blend of clays which shall approximate to the old German clay.

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CERAMIC ABSTRACTS

General

Clays and shales of Minnesota. F. F. GROUT AND E. K. SOPER. U. S. G. S., *Bull.* 678, (1919).—A general discussion of clay, its origin, geologic types of deposits, the mineralogic, chemical and physical properties of clay its classification and adaptability, the technology of clay and uses of clay products serves as an introduction to the more detailed consideration of Minnesota's clay and shale resources. The geologic history of the state is outlined and the clay deposits of the various formations stated together with the adaptability of the materials. Refractory clays occur in the southwestern part of Minnesota, and are derived in part from the Archean and in part from the Cretaceous formations. Semi-refractory materials, the only source of which is the Cretaceous, are not fully explored. Prospecting and drilling should be employed in searching for these valuable deposits. The Decorah and Cretaceous shales and the Pleistocene red drift constitute the chief sources of non-refractory vitrifying clays. Among such materials may be mentioned the Huronian slates which when mixed with clay from the drift will make a fancy brick of excellent grade. The gray drift is unsuited for brick manufacture until the pebbles have been removed. With such treatment it may make not only brick but excellent drain tile. Non-refractory clays that soften rapidly as their fusion temperature is approached and are suitable only for common brick, draintile, fireproofing or slip glazing, are of widespread occurrence and include nearly all gray drift clays and gray laminated clay silts. The lakes and swamps throughout Minnesota, especially those which may be easily drained should receive careful consideration since clays occupying them may be of value. Greater exploration of clays and shales by drilling and stratigraphic methods of prospecting is especially recommended. The clays and shales of the state are considered by counties and the deposits described in detail. Numerous photographs, sections, analyses and tests are included in the report.

E. D. ELSTON.

Summary report of the Mines Branch of the Dept. of Mines for 1918. Ottawa (1920).—Investigations of graphite and silica are summed up and a brief report of the Ceramic Division is included in which are given the results of tests made on materials from various localities in British Columbia, Eastern Ontario and Northern Ontario. Of especial interest is a brief discussion of some Canadian Bentonite deposits, and a series of pottery and fire clays from Northern Ontario, which resemble the clays described by Ries and Keele from the Musquodoboit Valley of Nova Scotia.

E. D. ELSTON.

Report on the barytes deposits of Georgia. J. P. D. HULL. Geol. Surv. of Ga., *Bull.* 36 (1920).—Barite, the deposits, geographic distribution and uses of barytes, together with production, imports and consumption of the material are briefly treated in the introduction.

In Georgia, the deposits occur in the northwestern part of the state, mainly in the Appalachian Valley, the principal district being near Cartersville, Bartow County. Some deposits, however, occur in the Piedmont Plateau. Six types of deposits, according to mode of occurrence, are stated: (1) vein, (2) replacement, (3) breccia, (4) residual, (5) colluvial, (6) alluvial. Only the residual and colluvial types are of commercial importance although some of the vein deposits have been worked on a small scale. Two principal types of ore occur: (1) crystalline, either coarse or fine in texture, generally translucent in thin fragments and generally slightly bluish white in color, (2) granular, opaque, dull white and finely granular. Briefly, the deposits have originated apparently in the following manner: circulating meteoric and thermal waters dissolved barium from the feldspars and micas of crystalline rocks and carried it through faults and fractures to limestone formations where favorable conditions brought about deposition of barium sulphate, barytes. The report includes, maps, photographs, analyses and sections.

E. D. ELSTON.

Used plaster molds. ANON. *Tonind.-Ztg.*, 44, 397 (1920).—Old plaster molds are crushed and molded into brick. The voids are filled with fresh plaster which upon setting acts as a bond in forming the brick.

H. G. SCHURECHT.

Making the kiln crown waterproof. ANON. *Brit. Clayworker*, 29, 16 (1920).—One method consists in covering the crown with a layer of ashes, clay and brick bats and then laying on a cement-lime mortar. A mixture of cement with six times its volume of fine sand may then be applied in the form of four $\frac{1}{4}$ in. layers. The first three layers will tend to crack but the fourth will show very little cracking. For very thick crowns painting the crown with pitch each season will give satisfactory results. Where expense is not important one of the best methods is to cover the crown with a mixture of kieselguhr and clay dust and on this to lay specially made hollow blocks. Any water entering the joints between the blocks is stopped by the clay and kieselguhr and a particularly dry crown is formed. A somewhat cheaper but inferior material which may be used as a substitute for kieselguhr is a layer of ashes covered with 1 in. of clay dust.

H. G. SCHURECHT.

Thermal expansion of insulating materials. W. H. SOUDER AND PETER HEDNERT. Bur. Standards, *Sci. Paper* 352 (1919).—In the furnaces used for tests, the specimen was supported horizontally and a 2 mm. platinum wire hung over each end. Each wire, hanging through a hollow tube below the end of the specimen and extending downward through and below the furnace,

had at its lower end a vane (or weight) immersed in oil in order to dampen the vibrations. Heating was effected by electric resistance coils (outside, inside, and end coils). The length changes were determined with a comparator consisting of two microscopes rigidly clamped on an invar bar at a distance from each other equal to the length of the specimen (30 cm.). The microscopes were first sighted on a standard-length bar kept at constant temperature, and then on the vertically suspended wires which were in contact with the ends of the specimen. Data on the thermal expansion of 40 samples of various kinds of porcelain are presented. The expansion curves of porcelains may be divided into three classes: Straight-line, concave and convex curves. The expansion curves of most materials are concave. No marked set or permanent change in dimension due to the heat treatment was observed. Porcelains having low coefficients exhibited marked resistance to sudden temperature changes. Most phenol condensation products (bakelite, condensite, formica, etc.) shrink and lose weight when subjected to temperatures above 60° C. Marble and limestone showed a permanent growth when subjected to heat treatment. On cooling below room temperature, it was found that marble has a negative coefficient of expansion. A. J. LAMBERT.

Kaolin sand. ANON. *Tonind.-Zeit.*, 44, 593 (1920).—In washing kaolins considerable sand is removed and heretofore most of it was thrown in the waste piles. This sand is often angular and makes good sand for mortar if those particles above 7 mm. are removed. The glass industries use that material which is free from mica. Another use is for refractory purposes. The material when finely ground is an excellent substitute for flint in stoneware, sanitary ware and porcelain. The coarse material containing mica is used for making ornamental cement ware, since the mica gives it a glistening appearance. H. G. SCHURECHT.

German clays. E. POMMER. *Tonind.-Zeit.*, 44, 470 (1920).—In the substitution of German clays for foreign clays the use of a number of clays is approved. Although taken from the same pit, clays often vary considerably in their physical properties. Using a number of clays in a body would minimize the changes due any variations of one clay. H. G. SCHURECHT.

Kaolin as a filler for paper. ANON. *Tonind.-Zeit.*, 44, 294 (1920).—English china clay is more refined and clean than most German kaolins, and when German kaolins are refined to the same degree of purity they may be used in the place of china clay for paper. Kaolins as a rule have a moisture content of 10 per cent whereas English china clays have a moisture content of 15 per cent. With regard to the use of German kaolin for paper making the following articles have been published in *Papier Zeit.*: (1912) 845, (1908) 1404, (1914) 2658, (1912) 2863. H. G. SCHURECHT.

Ceramic processes associated with colloid phenomena. A. V. BLEININGER. *Jour. Ind. Eng. Chem.*, 12, 436-8 (1920).—The colloidal character of clays

was recognized as early as 1874. Recent work of Jerome Alexander in ultra-microscopic examination has shown that the Brownian movement is observed with practically every type of clay suspended in water. Upon adding solutions of salts to clays an appreciable amount of the basic ion is absorbed but practically none of the acid ion. Deeply colored solutions of metallic salts may thus be decolorized by passage through clay. In the casting process and in washing clays the addition of alkaline reagents is effective in reducing the water content required to keep the mass in the liquid condition. Coagulating reagents, acids, and salts, are used to increase the plasticity and strength of certain clays and to thicken suspensions of glazes and enamels. All the phenomena of deflocculation and coagulation occur in phases. Thus the addition of alkali to a clay suspension brings about first a decided viscosity minimum, followed by alternating maxima and minimum until finally the phases merge in a definite direction. The coagulating ions apparently increase in effectiveness proportionately with their valence. An interesting phenomena observed with clay suspensions is the electrical deposition of the particles by a direct current upon the positive electrode against the flow of water away from it. This is the basis of the invention of Schwerin for removing clay from positively charged particles (iron bearing minerals) and depositing the former upon a metallic belt or revolving drum. The migration velocity is that of the heavier ions and the voltage determines the degree to which water has been eliminated. In dealing with clays in the plastic state it seems from the researches of Bingham that we must differentiate between viscous and plastic flow in that the yield point of the former is zero and of the latter finite. The aging of clays improves their plastic working quality and it is believed that this is due in part to the formation of organic acids, caused by bacterial action or chemical processes. The addition of small amounts of reagents like Al_2Cl_6 to kaolins brings about similar results provided the material is stored for some time, but no change is observed with the more impure materials. The presence of electrolytes affects not only the magnitude of the contraction in drying but the capillary flow of the water through the clay as well. After the evolution of most of the chemically combined water in burning a clay takes up eagerly sulphur dioxide and trioxide. In this state it possesses marked catalytic properties, as in the oxidation of sulphur dioxide to trioxide, the formation of ethylene, etc. It is possible that this characteristic of dehydrated clays may find uses in the technical application of a number of chemical reactions. Although surface tension is probably the most important factor in bringing about the condensation of clays in the vitrification process, vapor pressure undoubtedly enters into the case in dealing with substances showing a vapor tension sufficiently high or in the admixture of inert materials with those of a more volatile character. In all the silicate reactions at higher temperatures diffusion through the semi-rigid mass plays an important role. A. J. LAMBERT.

Annual Report on the Mineral Production of Canada during 1918. Can. Dept. of Mines, Mines Branch, Ottawa (1919).—The 1918 mineral production of Canada as a unit and by separate provinces is shown by numerous tables.

E. D. ELSTON.

Preliminary statement on the mineral production in the Province of Quebec during 1919. Prov. of Quebec, Dept. of Colonization, Mines and Fisheries, Bureau of Mines, Quebec (1920).—Statistical tables, subject to revision, set forth the mineral production of Quebec for 1919. Brief notes concerning the asbestos, chromite and magnesite industries are included in the report.

E. D. ELSTON.

Bauxite and aluminum in 1918. J. M. HILL. U. S. G. S., *Min. Res.*, 1918, Pt. 1 : 19, Mar. 16, 1920.—Notes on high-alumina clays are included in the report which is a brief résumé of the domestic and foreign bauxite and aluminum resources.

E. D. ELSTON.

Talc and soapstone in 1918. J. S. DILLER. U. S. G. S., *Min. Res.*, 1918, Pt. 11 : 24 (1920).—The imports, domestic production and world production of talc are tabulated and the occurrence, distribution and uses of talc are briefly considered.

E. D. ELSTON.

PATENTS

Ceramic composition. O. GERBER. U. S. 1,336,740, April 13, 1920. A mixture of pulverulent glass, china and earthenware molded to shape and fired.

Ware-support for ceramic firing. B. B. SWINNERTON. U. S. 1,336,762, April 13, 1920. This is a sagger designed particularly for use on the trucks of tunnel-kilns, but usable in other connections. It comprises a series of open-ended tubes, rectangular in cross-section each provided with one longitudinal shelf. These tubes are adapted to be superposed and also spaced apart by distances equal to their own widths. Within these spaces other longitudinal shelves are placed thus forming in substance other saggars. When used in open fire kilns these open-ended tubes are provided with end closures.

Furnace gas-producer. L. M. UNDERWOOD. U. S. 1,337,298, April 20, 1920. Individual gas-producers are placed at each fire-box of a kiln. The fire is built upon a plurality of hollow bars each provided with a series of up-standing twyers. Steam and air are blown into these hollow bars and through the twyers into the fuel bed, at first in quantities sufficient to burn the fuel and heat the kiln. Then the amount of air is cut down and the furnace operated as a producer. Air for combustion of the producer gas is added in the bags.

Tunnel kiln. C. J. KIRK. U. S. 1,337,454, April 20, 1920. This is a twin tunnel kiln very similar to that disclosed in the patent to Kirk, U. S. 1,332,501.

March 2, 1920, with the difference that a series of vertical open-ended tile form the outer side walls of the tunnels and the convection currents set up therein prevent direct radiation from the side flues upon the ware.

Gas burner for furnaces. J. G. HESS. U. S. 1,311,515, July 29, 1919. This is a burner designed for use in a continuously operated, reversible furnace. Associated with each burner is a checker-work through which air for combustion is drawn and preheated. Two air ducts lead upward from this checker-work. The gas duct is situated above the burner, a branch flue leading down between the two hot air flues. The air and gas are led away to the burner proper and burned. By this arrangement the gas is sufficiently preheated by its passage between the hot air flues to obviate the wasteful necessity of passing it through heated checker-brick. When natural gas is used which does not require this preheating which is necessary when using producer gas, the gas may be led to the burner from the sides without passing between the hot air ducts. It is thus a relatively simple matter to change from one gas to another. The inventor claims a substantial saving per day when burning producer gas over the old double checker system with a better combustion, a brighter fire and a tendency to avoid sulphur.

Filtering compound. L. W. SHULL. U. S. 1,336,591, April 13, 1920. A mixture is made comprising kieselguhr, 60-80 per cent, asbestos 10-30 per cent, and 10-15 per cent of whiting or its equivalent. The whole is made into paste with the addition of water, shaped and burned at a temperature ranging from 1800 to 3000° F. A porous body results which is said to possess the property of holding back germs and micro-organisms present in liquids filtered through it. G. E. MIDDLETON.

Refractories

The siliceous rocks. L. BERTRAND AND A. LANQUINE. *Ceramique*, **22**, 226-8 (1919); **23**, 21-3 (1920).—The use of geology in the selection of raw material for silica brick is emphasized. Silica originally occurs in nature as quartz veins and in mica schists. Secondary products resulting from the destruction of these are known as sandstone, grit stone and quartzites. Chalcedony is distinguished from quartzites by its cryptocrystalline structure. The best material used for silica brick is a quartzite from Westerdale which has a microcrystalline cement and is of the tertiary age. Quartzites of the Rhine valley are of second quality. H. G. SCHURECHT.

Zinc retorts. *Tonind.-Ztg.*, **44**, 310 (1920).—Calcined clay or porcelain (1-5 mm.) may be used as grog. Quartz produces a porous retort with a low resistance to sudden temp. change and is, therefore, not recommended. Coke is sometimes added to make the retorts more resistant to sudden temp. change. Retorts made of carborundum and zircon are very resistant to sudden temp. changes. The use of a glaze which softens at 900° C is recommended. H. G. SCHURECHT.

The reversible expansion of refractory materials. H. J. HODSMAN AND J. W. COBB. *J. Soc. Glass Tech.*, 3, 201-221 (1919).—The problem of expansion and contraction of refractories is of first importance in the glass industry, especially as it relates to glass pots. Silica refractories, when burned, undergo a permanent expansion while fire clay refractories undergo a permanent contraction. When heated after the first burning all types of refractories undergo an expansion which is reversible on cooling. It is this reversible expansion and contraction that is here reported. The test specimens examined in an electric tube furnace were usually about 8 in. long by 1 in. diam. Expansion up to 1000° C was studied. Calcined alumina, magnesia brick, carborundum, calcined kaolin and hard calcined ball clay were found to expand fairly regularly over the whole range to 1000° C and such results do not indicate the existence of molecular changes. As contrasted with this the silica refractories (quartz) showed great irregularities. These silica refractories were found to expand fairly regularly and not much more than kaolin up to 500° C, from 500° to 600° C the expansion increased greatly and from 600° to 1000° was practically nil. The great expansion at 500° to 600° C accompanies the inversion from α to β quartz. Nothing in the results obtained was found to indicate a tridymite change between 600° and 1000° C. Fire clays in general and pot clays in particular were found to show expansions which were like kaolin on the one hand or like silica on the other hand in proportion to the silica content. Mixtures of half fireclay and half silica (about 80 per cent SiO_2 in the total mix.) behaved substantially the same as pure SiO_2 . Obviously glass pots made from kaolin-ball clay mixtures or other mixtures containing little or no free SiO_2 behave very differently from pots of high silica content. The latter must be arched very carefully especially between 500° and 600° C. One point which remains unexplained is the contraction just below 600° C which occurs in the cooling of both fire clay and silica materials and which actually exceeds the corresponding expansion during heating. This is especially marked with silica and fire clays and indicates great possible danger from cracking at this point during cooling. The expansion from 0° to 1000° C was about $\frac{1}{2}$ of 1 per cent for most refractories, but for magnesia brick it was over 1 per cent. The actual figures were: alumina (plus 10 per cent ball clay for plasticity) 0.62 per cent; silica (quartzose), first heating—later heatings were slightly different, 0.68 per cent; kaolin, 0.53 per cent; ball clay, 0.57 per cent; magnesia brick, 1.27 per cent; Farnley fire clay, first heating, 0.58 per cent; Scotch fire clay, 0.61 per cent; carborundum, 0.47 per cent; equal parts of clay and ganister fired to cone 10, 0.65 per cent.

C. H. KERR.

The porosity and volume changes of clay fire bricks at furnace temperatures. GEORGE A. LOOMIS. Bur. of Standards, *Tech. Paper* 159.—This paper deals with the permanent changes in porosity and volume of clay fire bricks when reburned to temperatures at or above those to which they were originally fired. These were measured for a series of temperatures to determine what relation, if any, might exist between these changes and the

deformation of the same bricks under load at furnace temperatures. The possibility of such a relation is suggested by the fact that contraction of clay on heating and decrease in porosity are, to a certain extent, indications of the amount of softening of the mass due to the action of fluxes present and hence indicative of decreased resistance to deformation under pressure or decreased viscosity. Softening point determinations were also made to determine what relation these might bear to the results of the load test.

The results of tests on a large number of clay fire bricks from various parts of the country show that bricks which withstand a load test of 40 pounds per square inch at 1350 degrees C without marked deformation show no marked changes in porosity or volume up to 1425 degrees C. Bricks which do not withstand the test generally show appreciable contraction or expansion accompanied by considerable decrease in porosity. Bricks which showed overburning and the development of vesicular structure below 1425 degrees C, by marked expansion or increase in porosity invariably failed under load. In general, brick which show a decrease in porosity exceeding 5 per cent or a volume change exceeding 3 per cent (amounting to approximately 1 per cent in linear dimensions) when refired to 1400 degrees C fail to pass the load test.

No definite relation could be determined between the softening point of a brick and its ability to withstand pressure at high temperature. All bricks softening below cone 28 failed completely in the load test. Some showing quite high softening points also failed, probably due to the use of an inferior bond clay in the mixture or too small an amount of bonding material.

A. J. LAMBERT.

Results of some tests on refractories. M. L. HARTMAN AND O. A. HOUGEN. *Brick Clay Record*, 56, 934 (1920).—Spalling losses were determined on various fire brick after heating to 1350° C and cooling with an air blast 10 times. Hot abrasion tests were also made by heating brick to 1350° C and holding same against a carborundum grinding wheel at a constant pressure. The depth of abrasion was then used as a means of comparison. The results obtained are as follows:

| | Number of coolings | Per cent spalling loss | Abrasion inches |
|---|-----------------------|------------------------------|--------------------|
| 1 Bonded carborundum (carbofrax C)..... | 10 | 0.3 | 0.01 |
| 2 Bonded carborundum (carbofrax B)..... | 10 | 6 | 0.3 |
| 3 Bonded carborundum (carbofrax C)..... | 10 | 8 | .01 |
| 4 Grade A fire clay..... | 10 | 9 | .11 |
| 5 Recrystallized carborundum (refrax).... | 10 | 12 | .07 |
| 6 Bauxite..... | 10 | 43 | .04 |
| 7 Zirconia (natural)..... | 10 | 53 | .06 |
| 8 Grade B fire clay..... | 10 | 65 | .09 |
| 9 Grade C fire clay..... | 10 | 90 | .07 |
| 10 Chrome..... | 7 | 100 | .27 |
| 11 Silica..... | 4 | 100 | .. |
| 12 Magnesite..... | 3 | 100 | 2.50 |

H. G. SCHURECHT.

PATENTS

Ceramic composition and method of making it. W. M. W. HORN. U. S. 1,335,167, March 30, 1920. This is a so-called refractory material suitable for use in making heating elements of radiators and capable of withstanding changes in temperature between 20- and 120- C. It comprises plastic fire clay, pulverized chamotte and lean kaolin, and is substantially free from fragments of quartz and feldspar and of alkalis and alkaline earths.

G. E. MIDDLETON.

Glass

Colored hollow glassware. ANON. *Die Glas-Industrie*, 31, 57-8 (1920). —Yellow is one of the difficult colors to handle. Antimony oxide, chromium and uranium oxides, iron and manganese oxides, also sulfur and carbon are used. Typical formulas are:

Dark yellow

| | |
|----------------------|-------------------|
| Sand..... | 100 kg. |
| Potash..... | 10 kg. |
| Soda ash..... | 25 kg. |
| Gypsum..... | 16 kg. |
| Antimony oxide..... | $\frac{1}{4}$ kg. |
| Charcoal powder..... | 3 liters |

Golden yellow

| | |
|------------------------|----------------|
| Sand..... | 100 |
| Potash..... | 5 |
| Soda ash..... | 30 |
| Lime..... | 14 |
| "Hirse" (millet)... | $2\frac{1}{2}$ |
| MnO ₂ | $\frac{3}{4}$ |

Antique yellow

| | |
|------------------------|--------------------|
| Sand..... | 100 kg. |
| Potash..... | 5 kg. |
| Soda ash..... | 30 kg. |
| Marble..... | 18 kg. |
| MnO ₂ | $5\frac{3}{4}$ kg. |
| Iron scale..... | 2 kg. |
| Sulfur..... | 300 g. |

Amber yellow

| | |
|---------------------|---------------|
| Sand..... | 100 |
| Potash..... | 5 |
| Soda ash..... | 30 |
| Lime..... | 15 |
| Saltpetre..... | 2 |
| Antimony oxide..... | $\frac{1}{4}$ |
| Sodium uranate..... | $\frac{1}{2}$ |

Ivory yellow

| | |
|------------------------|-----|
| Sand..... | 100 |
| Soda ash..... | 22 |
| Saltpetre..... | 4 |
| Feldspar..... | 18 |
| Fluorspar..... | 12 |
| Kryolite..... | 10 |
| MnO ₂ | 4 |
| Red lead..... | 4 |
| Iron oxide..... | 1 |

Brown.—MnO₂ and Fe₂O₃ are commonly used, also carbon and the organic materials like millet ("hirse") flour, etc.

| Brown | |
|------------------------|-----|
| Sand..... | 100 |
| Soda ash..... | 33 |
| Lime..... | 10 |
| MnO ₂ | 14 |
| Powdered coke..... | 1 |

| Reddish brown | |
|--------------------------------------|-------------------------------|
| Sand..... | 100 |
| Soda ash..... | 33 |
| Lime..... | 15 |
| Fe ₃ O ₄ | 1 ³ / ₄ |
| MnO ₂ | 9 ¹ / ₂ |

| Fiery brown | |
|--------------------|-----------------------------|
| Sand..... | 100 |
| Soda ash..... | 33 |
| Lime..... | 16 |
| Powdered coal..... | 1 |
| Flour..... | ³ / ₄ |

| Fawn colored | |
|-----------------|-----|
| Sand..... | 100 |
| Lime..... | 5 |
| Potash..... | 38 |
| Bone ash..... | 22 |
| Iron oxide..... | 2 |

Gray.—A neutral gray is obtained by using: Sand, 100; potash, 10; soda ash, 23; lime, 14; nickel oxide, 1¹/₂; iron oxide, 2; copper oxide, 1; cobalt oxide, ¹/₅ kg. *Violet* is obtained by using MnO₂ and Fe₂O₃. *White* glasses are made from the following:

| Milk glass | |
|-------------------|---------|
| Sand..... | 100 kg. |
| Soda ash..... | 12 kg. |
| Potash..... | 5 kg. |
| Feldspar..... | 15 kg. |
| Fluorspar..... | 10 kg. |
| Saltpetre..... | 2 kg. |
| Kryolite..... | 10 kg. |
| Nickel oxide..... | 4 gr. |

| Enamel glass | |
|----------------|-----|
| Sand..... | 100 |
| Potash..... | 20 |
| Saltpetre..... | 5 |
| Tin oxide..... | 12 |
| Red lead..... | 80 |
| Borax..... | 4 |
| Bone ash..... | 12 |

| Milk glass | |
|----------------|-----|
| Sand..... | 100 |
| Soda ash..... | 15 |
| Feldspar..... | 18 |
| Fluorspar..... | 9 |
| Kryolite..... | 8 |
| Tin oxide..... | 4 |

| Opalescent glass | |
|------------------|-----|
| Sand..... | 100 |
| Soda ash..... | 30 |
| Feldspar..... | 35 |
| Fluorspar..... | 18 |
| Red lead..... | 6 |
| Nitre..... | 4 |
| Borax..... | 0.5 |

C. H. KERR.

The polariscope and its application to the glass industry. G. V. WILSON. *J. Soc. Glass Tech.*, 3, 256-8 (1919).—A polariscope consists of two essential parts, a polarizer and an analyzer. In the instrument described the polarizer consists of a pile of 10 or 12 clear, thin glass plates the bottom one blackened on the back. Polarized light is reflected to a Nicol prism, the analyzer. Glass objects placed between these show light transmitted in proportion to the amount of strain. By inserting a plate of selenite of suitable thickness between the analyzer and the test sample slight strains can be detected because the differences in color are accentuated. Sketches are given.

C. H. KERR.

The annealing temperatures of magnesia-soda glasses. S. ENGLISH AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 278-8 (1919).—The compositions of the glasses tested are shown in the following abstract (on MgO-Na₂O glasses, Davidson, Hodkin and Turner). The analyses follow:

| Glass No. | SiO ₂ | Na ₂ O | MgO | Minor constituents (CaO, Fe ₂ O ₃) and Al ₂ O ₃ | Total |
|-----------|------------------|-------------------|------|--|--------|
| 24 | 74.07 | 24.23 | 1.10 | 0.37 | 99.87 |
| 25 | 74.35 | 23.46 | 1.85 | .75 | 100.41 |
| 26 | 75.00 | 22.12 | 2.49 | .26 | 99.97 |
| 27 | 75.16 | 20.69 | 3.47 | .46 | 99.78 |
| 28 | 75.19 | 19.83 | 4.20 | .52 | 99.74 |
| 329 | 76.30 | 18.26 | 5.09 | .74 | 100.39 |
| 330 | 77.09 | 16.05 | 6.10 | .68 | 99.92 |
| 331 | 76.68 | 15.77 | 6.87 | .93 | 100.25 |
| 332 | 76.86 | 14.55 | 7.46 | .93 | 99.80 |
| 389 | 77.77 | 13.40 | 8.45 | 0.56 | 100.17 |
| 390 | 78.28 | 11.76 | 9.30 | .91 | 100.25 |

The following table shows annealing temperatures with comparisons for similar lime-soda glasses.

| Magnesia-soda glasses | | | Lime soda glasses | | |
|-----------------------|--|-----------------------|-------------------|------------------------------|-----------------------|
| Glass No. | Molecular percentage of magnesia (MgO) | Annealing temperature | Glass No. | Molecular percentage of lime | Annealing temperature |
| 1 | ... | 490° | 1 | ... | 490° |
| 24 | 1.66 | 495 | 2 | 1.62 | 496 |
| 25 | 2.77 | 502 | 3 | 2.81 | 501 |
| 26 | 3.71 | 505 | 4 | 4.11 | 508 |
| 27 | 5.16 | 510 | 5 | 4.84 | 512 |
| 28 | 6.23 | 519 | 6 | 6.73 | 526 |
| 329 | 7.48 | 524 | 7 | 8.00 | 538 |
| 330 | 8.95 | 530 | 8 | 8.75 | 552 |
| 331 | 10.02 | 543 | 9 | 10.01 | 562 |
| 332 | 11.01 | 560 | 10 | 11.14 | 581 |
| 389 | 12.21 | 583 | 11 | 12.41 | 601 |
| 390 | 13.38 | 616 | .. | ... | ... |

Curves drawn from these data show while the annealing temperatures are lower for the magnesia glasses, especially so in the softer glasses, with harder glasses, the annealing temperature rises faster in the magnesia than in the lime glasses and with very hard glasses might be about the same. However, within practical limits in ratio of soda to magnesia or lime, the magnesia glasses anneal at appreciably lower temperatures. If, in commercial glasses dolomitic lime is used in place of high calcium lime, a more ready annealing, may be expected.

C. H. KERR.

Magnesia-soda glasses. J. H. DAVIDSON, F. W. HODKIN AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 275-7 (1919).—Although magnesia is present in many glasses and often in considerable amounts still magnesia glasses, as such, are not yet of commercial importance. Magnesia-soda glasses of the following compositions were tried. All temps. are C.

| Glass No. | Approx. molecular composition | Working properties |
|-----------|--|--|
| 24 | 6SiO ₂ , 1.9 Na ₂ O, 0.1 MgO | At 1100-1200° very mobile. Did not cool so rapidly as the corresponding lime-glass. |
| 25 | 6SiO ₂ , 1.8 Na ₂ O, 0.2 MgO | Very mobile at 1200-1300°, but worked well. |
| 26 | 6SiO ₂ , 1.7 Na ₂ O, 0.3 MgO | Similar to 25. Retained its heat for considerable time. |
| 27 | 6SiO ₂ , 1.6 Na ₂ O, 0.4 MgO | Similar to 26. |
| 28 | 6SiO ₂ , 1.5 Na ₂ O, 0.5 MgO | Worked well and retained its heat. |
| 329 | 6SiO ₂ , 1.4 Na ₂ O, 0.6 MgO | Worked well at 1150-1200°. Thick foam on surface of glass requiring to be removed. |
| 330 | 6SiO ₂ , 1.3 Na ₂ O, 0.7 MgO | Worked well at 1150-1250°. Rather viscous and needed temperature of 1300° to enable to pour. Slight scum. |
| 331 | 6SiO ₂ , 1.2 Na ₂ O, 0.8 MgO | Melted 1400-1450°. Worked well at 1250-1350°. Viscous and stiff, but drew evenly into rod and tubing. |
| 332 | 6SiO ₂ , 1.1 Na ₂ O, 0.9 MgO | Similar to 331, but more viscous. |
| 389 | 6SiO ₂ , 1.0 Na ₂ O, 1.0 MgO | Metal very viscous even at 1400°, and inclined to be seedy and cordy. Tubing difficult to draw. |
| 390 | 6SiO ₂ , 0.9 Na ₂ O, 1.1 MgO | Very viscous. Boil difficult to remove even after 22 hours. Scum on surface. Easy enough to gather, but too stiff to draw even at red heat, and tubing and rod not good. |

Glasses Nos. 28 to 389 had a light blue tint. In general the magnesia glass closely resembled corresponding lime glasses. In large amounts it made melting difficult. There were, however, distinct differences. The viscosity of high magnesia glasses was greater than that of high lime glasses but the rate of change in viscosity seemed to be less than with the lime glasses. Magnesia glasses retained their heat longer. They also showed a tendency to raggedness or stringiness and a greater tendency to cordiness. The chief apparent advantages of magnesia glasses over lime glasses were: (1) retention of heat, (2) larger working range, (3) lower coefficient of expansion and (4) lower annealing temperature. A study of magnesia glasses may prove fruitful.

C. H. KERR.

The influence of lime on the value of Young's modulus of elasticity for the soda-lime glasses. J. R. CLARKE AND W. E. S. TURNER. *J. Soc. Glass Tech.*, **3**, 260-6 (1919).—Young's modulus of elasticity is defined as the ratio of the stress applied to the strain which the object undergoes. This ratio is obviously very important for the amount of strain that can be developed in a glass without fracturing it, is related to the elasticity. The method of determination was to observe the bending of a glass rod supported at the ends and weighted at the middle. The value for Young's modulus (E) was calculated as $100 \times l^3 \div 12 \times r^4 d$ where l = distance in cm. between knife edges, r = radius of the rod and d = mean depression for 100 grams weight. The results are shown in the following table.

| Glass | Composition | | | | | | Value of E |
|---------|--|--------------------------------|--------------------------------|-------|------|-------------------|-----------------------------|
| | SiO ₂ | Al ₂ O ₃ | Fe ₂ O ₃ | CaO | MgO | Na ₂ O | |
| 1..... | 74.25 | 0.42 | 0.16 | Trace | .. | 25.37 | 5784 kg./mm. ² |
| 2..... | 73.90 | .21 | .14 | 1.57 | .. | 23.80 | 5930 kg./mm. ² |
| 3..... | 74.05 | .22 | .14 | 2.63 | .. | 23.00 | 6175 kg./mm. ² |
| 4..... | 74.02 | .29 | .15 | 3.79 | .. | 23.15 | 6332 kg./mm. ² |
| 5..... | 73.77 | .34 | .18 | 4.54 | 0.16 | 20.78 | 6426 kg./mm. ² |
| 6..... | 73.21 | .55 | .62 | 6.22 | .22 | 19.38 | 6700 kg./mm. ² |
| 7..... | 73.97 | .76 | .18 | 7.56 | .23 | 17.30 | 6804 kg./mm. ² |
| 8..... | 74.82 | .38 | .09 | 8.15 | .26 | 16.30 | 6965 kg./mm. ² |
| 9..... | 74.92 | .38 | .17 | 9.26 | .31 | 14.88 | 7034 kg./mm. ² |
| 10..... | 74.59 | .48 | .17 | 10.40 | .29 | 14.22 | 7249 kg./mm. ² |
| 11..... | 74.93 | .38 | .16 | 11.63 | .31 | 13.02 | (6912) kg./mm. ² |
| 12..... | (6SiO ₂ , 1.1 CaO, 0.9 Na ₂ O) | | | | | | 7642 kg./mm. ² |
| 16..... | 66.67 | 1.43 | .32 | 18.06 | .85 | 12.72 | 8343 kg./mm. ² |

Values for E were also calculated from the compositions, using Winkelmann and Schott's factors, but these factors were found to be inaccurate. A comparison of the old and new factors is shown in the table:

| Oxide | W. & Schott's factor | New factor |
|--------------------------------------|----------------------|------------|
| SiO ₂ | 65 | 40 |
| Na ₂ O..... | 100 | 110 |
| Al ₂ O ₃ | 160 | 120 |
| Fe ₂ O ₃ | .. | 120 |
| CaO..... | 100 | 240 |
| MgO..... | 500 | 300 |

Using these new factors in calculating E gives results close to those determined experimentally.

The general conclusions are: (1) increases in lime cause a corresponding and very marked increase in elasticity, (2) Winkelmann and Schott's conclusion, indicated by the factors assigned, that soda and lime are alike in their effects on elasticity, is shown to be incorrect, (3) Young's modulus of elasticity can be satisfactorily calculated from composition, using the new factors given above.

C. H. KERR.

Glass for table working. M. W. TRAVERS. *J. Soc. Glass Tech.*, 253-6 (1919).—Many years ago a German manufacturer stated that he made two kinds of lamp-working glasses, one deteriorated if kept over six months before working while the other was good for years. More recently many samples of both good and bad were submitted by an English firm and analyses showed that "the high quality glasses contained both soda and potash, while the low quality glasses contained soda alone." The author, therefore, recommended that glass for table-working tube be made to approximately the following composition: silica, 68; alumina, 4; calcium oxide, 7.5; potassium oxide, 7; sodium oxide, 13 per cent. From a lamp-working standpoint the glass is good but it plains only at a high temperature and it is expensive. An unusually fine piece of old table-working glass analyzed: silica, 61.26; alumina, 7.92; calcium oxide, 9.25; potassium oxide, 2.98; sodium oxide, 1.08; antimony oxide, 3.45 per cent. A glass of such composition may be made by using feldspar and without adding potash in any other form. This seems to offer distinct possibilities.

C. H. KERR.

A simple apparatus for the detection of strain in glass. S. ENGLISH. *J. Soc. Glass Tech.*, 3, 258-60 (1919).—A home-made polariscope is described with all details necessary for construction.

C. H. KERR.

Note on the formation of glass. S. C. BRADFORD. *J. Soc. Glass Tech.*, 3, 282-5 (1919).—"Although it has been customary for years to regard glass as a supercooled liquid" the supposition is not helpful and "does not conform to the dictionary definition of a liquid as being in a state in which its particles are free to travel about." There is no sudden change when glass solidifies—the gradual change resembles the setting of a jelly. "The structure of gels is beginning to be understood and similar considerations appear to explain the formation of glass." "There are many indications that the solidification of glass is a crystallization process." "The development of visible crystals is dependent on the velocity of crystallization" and glasses, because of low heat conductivity and viscosity, have a very small velocity of crystallization which permits a great degree of overcooling. Evidences point toward glass as a crystalline formation. Physical properties are influenced least by monovalent ions, more by divalent ions, etc., the effects increasing enormously with valence. Opal glasses illustrate this. Another point is the effect of alkali on color development. For example, three glasses with nickel as coloring material and otherwise alike except for the nature of the alkali will show a fine deep violet with potash, a near-brown with soda and a yellowish brown with lithia. A study of glass as a crystalline product "might lead to useful results." The arguments are strong.

C. H. KERR.

Some experiments on glass for lamp-working purposes. J. D. CAUWOOD, J. H. DAVIDSON, F. W. HODKINS AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 266-74 (1919).—Attempts were made to produce glass suitable for lamp-

working, basing the results on analyses of six good foreign glasses. The analyses of these glasses follow:

| | (1) | (2) | (3) | (4) | (5) | (6) |
|--------------------------------------|-------|--------|--------|--------|-------|--------|
| SiO ₂ | 69.30 | 69.10 | 71.88 | 68.78 | 61.26 | 71.90 |
| As ₂ O ₃ | Trace | 0.10 | 0.10 | .. | ... | .. |
| Sb ₂ O ₃ | ... | .. | .. | 0.52 | 3.45 | 0.48 |
| Al ₂ O ₃ | 4.05 | 3.10 | 2.75 | 4.04 | 7.92 | 3.69 |
| CaO..... | 8.28 | 6.89 | 4.90 | 7.75 | 9.25 | 7.99 |
| MgO..... | 0.07 | 0.20 | 0.20 | 2.34 | 0.20 | .. |
| K ₂ O..... | 4.96 | 6.38 | 1.98 | 2.60 | 3.98 | 0.32 |
| Na ₂ O..... | 12.80 | 14.50 | 18.57 | 15.72 | 13.08 | 14.90 |
| MnO..... | 0.20 | 0.10 | 0.10 | 0.20 | 0.30 | 0.75 |
| Fe ₂ O ₃ | .18 | .. | .. | .25 | .30 | .31 |
| | 99.84 | 100.37 | 100.48 | 100.20 | 99.74 | 100.34 |

Glasses corresponding to analyses 1 to 3 were the best all around lamp-working glasses and especially those based on No. 2. The best glass made was from batch: sand, 1000; feldspar, 367; limestone, 220; soda ash (95 per cent), 448; potash, 151; magnesia (90 per cent), 3.7; manganese (87 per cent MnO₂), 2.75 lbs. This is very similar to a German lens glass for artificial eyes, which was reproduced by a batch: sand, 1000; feldspar, 300; limestone, 110; soda ash (95 per cent), 375; potash (92 per cent), 205; magnesia, 10; white arsenic, 5; manganese, 3 lbs. Results indicate that arsenic and antimony should be omitted from lamp-working glasses for they seem to cause blackening when worked in the flame. The addition of nitre had no influence upon this tendency to blacken. Apparently this tendency is not due to lead impurity in the arsenic or antimony. Possibly glasses of distinctly different type also may be very good for lamp-working and experiments are under way. There are indications that a high lime glass may be good. In one set of tests a glass with equal molecular proportions of soda and potash worked very well.

C. H. KERR.

The durability of lime-soda glasses. J. D. CAUWOOD, J. R. CLARKE, CONSTANCE M. M. MUIRHEAD AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 228-37 (1919).—Glasses with less lime than in the glass 1.5 Na₂O, 0.5 CaO, 6 SiO₂ are not resistant to the attack of reagents including water, caustic alkali, sodium carbonate and hydrochloric acid—that is glasses made from batches varying between (a) sand 1000, soda ash 590 and (b) sand 1000, soda ash 441, limestone, 139 are unsatisfactory. Such glasses are not only dissolved by reagents but are hygroscopic. Substituting lime for soda increased resistance to all kinds of liquids. In glasses containing only a very small amt. of lime, water is the most corrosive reagent and strong caustic alkali the least. For the production of a fairly rapid melting glass suitable for automatic or semi-automatic machines batches varying from sand 1000,

soda ash 412, limestone 166, to sand 1000, soda ash 353, limestone 194 are satisfactory. The glasses are sufficiently durable for ordinary use.

C. H. KERR.

The manufacture of table ware in tank furnaces. R. L. FRINK. *J. Soc. Glass Tech.*, 3, 242-9 (1919).—Flint glass as here referred to is meant to include all glasses having composition between the limits, silica 78, lime 6, soda plus potash 16, and silica 62, lead oxide 26, potash plus soda 12 per cent. Flint glasses are divided into two classes: lead flints, including optical glass, bulb glass, cut-glass blanks, table ware; and lime flints, including bulb glass, blown stem ware, pressed ware, blown ware (as chemical ware, vases, chimneys) pressed cutting blanks and blown pressed ware both hand and machine made. The old idea that lead glass could not be successfully melted in a tank furnace on account of reduction of the lead has been proven erroneous for good results are obtained. Furnace operators who have been trained in pot furnace work where a long reducing flame is maintained have difficulty in learning to operate a tank requiring oxidizing conditions. It is claimed that when soda or potash or a combination of the two exceeds 17 per cent it is very difficult to make glass free from striae and capable of ready annealing. If producers are used for tank furnaces an ample and uniform quantity of gas should be provided. Additional requirements for successful work include (1) air supply at suitable temperature to effect complete combustion, (2) prompt removal of gases of combustion, (3) unconsumed gases must not come in contact with melting batch, (4) no furnace should deliver less than 9 lbs. of glass per sq. ft. of melting area per hr. to insure first quality glass.

C. H. KERR.

A proposed standard formula for a glass for lamp-workers. F. W. BRANSON AND F. H. BRANSON. *J. Soc. Glass Tech.*, 3, 249-53 (1919).—A pre-war imported tubing which was entirely satisfactory analyzed: SiO_2 69.64; Al_2O_3 3.02; Fe_2O_3 0.06; MnO 0.18; CaO 6.40; MgO 0.37; K_2O 6.98; Na_2O 13.36. No Sb_2O_3 or As_2O_3 were present. The new standard formula developed from the basis of this analysis and known as batch No. 6 is as follows: sand, 1104; potash feldspar, 400; limestone, 222; saltpetre, 213; soda ash (95 per cent), 410; manganese (87 per cent MnO_2), 3. This glass is quite suitable for the making of plugs, stopcocks, bulbs, and so forth, and may be re-blown many times without devitrification. In exptl. melts 56 lbs. pots with 31 lbs. of batch added were maintained at 1340°C for 14 hrs. Analysis of finished glass gave: SiO_2 , 70.35; Al_2O_3 , 4.06; Fe_2O_3 , 0.04; MgO , 0.36; CaO , 7.1; MnO , 0.16; K_2O , 6.85; Na_2O , 10.66.

C. H. KERR.

The properties of lime-soda glasses. J. H. DAVIDSON AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 222-7 (1919).—The lime-soda glasses are by far the most important commercially. Glasses with almost any proportion of these three ingredients, silica, lime and soda, can be made if sufficient melting power is available but most commercial glasses approach the formula CaO , Na_2O ,

6 SiO₂. The ratio of CaO to Na₂O may vary considerably but usually the relationship is adhered to of 3 molecules of SiO₂ to one of CaO and Na₂O combined. Expts. were carried on to determine the working properties of glasses varying from 2 Na₂O, 6 SiO₂ to 1 Na₂O, 1 CaO, 6 SiO₂ also of two commercial glasses containing 0.81 Na₂O, 1.18 CaO, 3.94 SiO₂ and 0.75 Na₂O, 1.25 CaO, 4.63 SiO₂. Experiments with pots holding 28 lbs. were hardly satisfactory—with 56-lb. pots the results were good. While lime-containing glasses have usually been regarded as readily devitrified these experiments showed that devitrification decreased as lime increased. Glasses with less CaO than in the glass 1.5 Na₂O, 0.5 CaO, 6 SiO₂ should be avoided. Glasses from 1.4 Na₂O, 0.6 CaO, 6 SiO₂ to 1 Na₂O, 1 CaO, 6 SiO₂ are all durable. For semi-automatic machines glasses from 1.4 Na₂O, 0.6 CaO, 6 SiO₂ to 1.2 Na₂O, 0.8 CaO, 6 SiO₂ are recommended. These simple batches may not be the best but serve as a basis for adding small amts. of other materials. Some alumina from feldspar or clay should usually be added. Glasses with about 1 Na₂O, 1 CaO, 6 SiO₂ or one of the two commercial glasses given above are recommended for tanks with hand operation because they set rapidly.

C. H. KERR.

The glass furnace—a contribution to the saving of fuel. ANON. *Sprechsaal*, 53, 66-7 (1920).—The chief use of fuel is in the melting furnace and great economies can be effected by proper furnace design. In recuperative furnaces only the air is preheated while in regenerative furnaces both air and gas are preheated, hence the regenerative type is more economical. Many details of furnace design, especially flues, are discussed.

C. H. KERR.

The use of peat in the glass industry. A. F. WUROMUS. *Sprechsaal*, 53, 46-7 (1920).—Ash varies greatly from 5 to 50 per cent. Water content of good air-dried peat is 10-20 per cent. When handled by machine it is commonly made into bricks about 6 x 3 x 11 inches, weighing about 6 lbs. each. Drying may be done artificially or naturally, the air-dried peat being better. Peat with moderate ash and water contents is readily burned in gas producers and if water or ash is high some wood may be used with the peat. A 10-pot Siemens furnace operated with 3 producers will use 10-12,000 lbs. of good peat (and no wood) per 24 hrs., or if a poorer peat is used it will take 12-14,000 lbs. peat plus 2/3 of a cord of beech wood. With peat the flues must be cleaned out frequently.

C. H. KERR.

The characteristics of striae in optical glass. T. T. SMITH, G. E. MERRITT AND A. H. BENNETT. Bur. of Standards, *Sc. Paper* 373.—Striae are imperfections in optical glass which are revealed by, and cause consequent damage because of, their refractive index being slightly different from the surrounding glass. Various methods for detecting their presence are described and photographic illustrations by a highly sensitive method given. The comparative effects of striae on the definition given by binocular prisms, in which striae are present in different degrees, are exhibited by photographs of an artificial

star taken through these prisms. Prisms which had been discarded because of the presence of striae in them, except where these show up in dense nests, were found to give as good definition as those having no appreciable striae. The refractive indices of the striae were measured for a number of samples by a total reflection refractometer and found to be above or below that of the surrounding glass by about 2 in the fourth decimal place. From the investigation, it is concluded that in most visual work a few striae do real damage only when in focus or nearly in focus in the field of view. The scattering effect of a few striae is probably detrimental only in astronomical and certain kinds of microscopic work.

A. J. LAMBERT.

A deposit of granulite in Devonshire, *London Times Trade Supplement*, April 10, 1920.—A very large deposit of granulite has been discovered near Okehampton, Devonshire, England. Granulite contains silica, potash, soda, and alumina, and its use is economical in the production of glassware. An experimental furnace has been in use for some time, two others are being constructed, and it is anticipated that the commercial manufacture of glass will commence almost immediately. It is reported that it will be possible to manufacture glass bottles and jars very cheaply. The estimated cost of the material utilized on the spot amounting to 15s. od. (at normal rate \$3.65) per ton, compared with a cost of 2 pounds (\$9.73) per ton for the cheapest mixtures ordinarily used for making glass bottles.

A. J. LAMBERT.

The heat expansion of soda-lime glasses. S. ENGLISH AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 238-41 (1919).—In all glass making, especially in annealing, coeff. of expansion is important. Coeff. for glass under strain is higher than for the same glass when free from strain. Results of coeff. detns. on a series of glasses show that decreasing Na_2O and increasing CaO decreases the coeff.

| Approx. mol. composition | | | | | | Coeff. of linear expansion | Temp. range |
|--------------------------|---------------------|----------------------------|-------------------|--|--|-------------------------------|----------------|
| 1..... | 6 SiO_2 | 2.0 Na_2O | .. | | | 0.000001153 | 25.0-90.0° |
| 2..... | 6 SiO_2 | 1.9 Na_2O | 0.1 CaO | | | .000001106 | 25.3-89.8 |
| 3..... | 6 SiO_2 | 1.8 Na_2O | .2 CaO | | | .000001065 | 25.1-89.1 |
| 4..... | 6 SiO_2 | 1.7 Na_2O | .3 CaO | | | .000001021 | 25.3-89.8 |
| 5..... | 6 SiO_2 | 1.6 Na_2O | .4 CaO | | | .000000988 | 25.1-90.0 |
| 6..... | 6 SiO_2 | 1.5 Na_2O | .5 CaO | | | .000000947 | 24.6-90.6 |
| 7..... | 6 SiO_2 | 1.4 Na_2O | .6 CaO | | | .000000911 | 25.0-90.0 |
| 8..... | 6 SiO_2 | 1.3 Na_2O | .7 CaO | | | .000000870 | 25.0-90.0 |
| 9..... | 6 SiO_2 | 1.2 Na_2O | .8 CaO | | | .000000844 | 25.0-89.9 |
| 10..... | 6 SiO_2 | 1.1 Na_2O | .9 CaO | | | .000000810 | 25.0-90.0 |
| 11..... | 6 SiO_2 | 1.0 Na_2O | 1.0 CaO | | | .000000769 | 24.0-90.6 |
| 16..... | 3.94 SiO_2 | 0.81 Na_2O | 1.18 CaO | | | .000000882 | 25.0-89.5 |
| 17..... | 4.68 SiO_2 | .75 Na_2O | 1.25 CaO | | | .000000801 | 25.0-90.0 |

The relation between compn. and coeff. is thus shown to be represented by a straight line. Schott's factors for calculating coeff. of expansion from compn. are shown by the following table to be inaccurate or at least to be of narrow application.

| Glass No. | Calculated by Schott's rule | Experiment | Difference |
|-----------|--------------------------------|------------|------------|
| 1..... | 1053 | 1153 | —100 |
| 2..... | 1036 | 1106 | — 70 |
| 3..... | 1013 | 1065 | — 52 |
| 4..... | 993 | 1021 | — 28 |
| 5..... | 981 | 988 | — 7 |
| 6..... | 958 | 947 | + 11 |
| 7..... | 916 | 911 | + 5 |
| 8..... | 886 | 870 | + 16 |
| 9..... | 862 | 844 | + 18 |
| 10..... | 850 | 810 | + 40 |
| 11..... | 822 | 769 | + 53 |
| 16..... | 923 | 881 | + 42 |
| 17..... | 789 | 801 | + 12 |

C. H. KERR.

Glass pots. A. SIEBEL. *Tonind.-Zig.*, **44**, 303-4 (1920).—Stones in glass are often caused by highly aluminous flint clay which becomes detached from the pot through the solution of the more siliceous bond clay. The practice of using a highly aluminous flint clay for grog is criticised and the use of grog having the same composition as the bond clay is recommended, since the solution by the glass would be uniform in this case thus eliminating the possibility of stones to a large extent.

H. G. SCHURECHT.

Composition of Belgian table glass. *Schnurpfeil's Review for Glass Works*, **3**, No. 35, 549.—Sand 100 kg., carbonate of soda 33 kg., carbonate of lime 17 kg., nitrate of soda 3.5 kg., salt 1.5 kg., antimony oxide 150 gr., arsenic 150 gr., manganese 200 gr., cobalt oxide $\frac{1}{3}$ to $\frac{1}{2}$ gr.

R. J. MONTGOMERY.

Composition of brown bottle glass. *Schnurpfeil's Review for Glass Works*, **3**, No. 35, 551.—Sand 100 lbs., soda ash 34 lbs., lime 25 lbs., sulphate of soda 1 lb., calcined oats 1 lb., charcoal 8 oz.

R. J. MONTGOMERY.

Mosaic and enamels of the vatican. ANON. *Pottery Gaz.*, **45**, 518-9 (1920).—The mosaic is composed of glass and minerals. When the glass has melted the colored powders and minerals are added and thoroughly mixed after which they are slowly baked. The enamel is then taken out and molded into small palettes. To make a picture the artist takes a highly polished slab of plaster and sketches the picture with charcoal. With a piercer he then hollows out around the design leaving small holes in which a glue or "smalt" is placed. The mosaic cubes are then chipped to fit in these holes by means of small hammers.

H. G. SCHURECHT.

Machine making of window glass. DR. WENDLER. *Die Glas-Industrie*, 31, 33-4, 41-2, 49-50 (1920).—An historical résumé of machine methods, chiefly American.

C. H. KERR.

A note on blue glass. J. W. MELLOR. *Trans. Eng. Ceram. Soc.*, 18, 478-80 (1919).—Adding a few per cent Co_2O_3 to lamp bulb glass was found to cause filaments, viewed through such glass, to appear red. It was desired to cut out these red rays. CuO was not satisfactory but a small amt. of Cr_2O_3 with the Co_2O_3 proved satisfactory. Absorption spectra are shown.

C. H. KERR.

PATENTS

Machine for making carboys or large glass containers. H. M. BROWN. U. S. 1,334,647 and 1,334,648, March 23, 1920. These machines are designed for making carboys or other large containers provided with internally threaded mouth portions. Glass is forced into a mold in contact with the neck of a newly formed carboy and around a collapsible, threaded mandrel. The molten glass for the mouth portion welds with the neck of the carboy. The mandrel is rotated to thread the mouth of the carboy internally, collapsed and withdrawn.

Method of manipulating glass. F. L. O. WADSWORTH. U. S. 1,334,725, March 23, 1920. As molten glass flows downward from an orifice into succession of molds, the stream is periodically cut to allow charge of the proper amount to fall into the waiting molds. The cutting blades used here when brought together form a conoidal pocket in which the arrested stream gathers, swells laterally and is chilled. The blades are then separated and this enlarged gob allowed to fall into a mold.

Conveyor for glass-ware. J. L. HIATT. U. S. 1,334,453, March 23, 1920. Molded articles of glass are placed upon a conveyor and moved, single file, onto the surface of a rotary disc at the mouth of the leer, the lineal speed of the disc being less than that of the conveyor whereby the articles are closely assembled. When substantially half the peripheral surface of this disc has been filled, a rotating arm sweeps the articles off upon the forwardly moving leer pan.

Method and apparatus for drawing and annealing sheet-glass. W. S. TEMPLE and J. A. KEALEY. U. S. 1,334,569, March 23, 1920. A plain sheet of glass is drawn vertically upwardly from the tank and through a vertical leer without coming into surface contact with anything. A bait is used to initiate the draw but thereafter vertical moving chains carrying clamping devices support the edges of the sheet and carry it upward. As the sheet approaches the top of the leer parts are cut off and removed. The operation is thus continuous.

Glass-blowing apparatus. F. W. STEWART. U. S. 1,335,533, March 30, 1920. By means of this apparatus, the blower, when standing upon an ele-

vated platform with this mold located below is able to control, by means of pedals, both the mechanism for opening the mold and the spraying device, whereby, unaided, he is able to operate both the mold-opening device and the spraying device, and thus can dispense with the extra boy usually employed for this purpose.

Process of making vacuum bottles. C. F. P. ANDERS. U. S. 1,335,544, March 30, 1920. The inner and outer receptacles are made of such shape and size that the inner may be inserted through the upper end of the outer and supported by an interposed spiral spring at the base thereof while the two are joined at their upper edges. This arrangement makes for simplicity of operation.

Apparatus for drawing glass cylinders. J. H. CAMPBELL. U. S. 1,335,653, March 30, 1920. A series of drawing units is provided, each unit composed of two fixed but independent pots, a single movable heater for the two pots, a drawing apparatus for each pot, and a single shiftable hoist for each unit.

Vial-machine. H. F. HAGEMEYER. U. S. 1,335,733, April 6, 1920. This machine acts on glass tubing making therefrom glass vials. The blank tube as received by the machine contains material for two vials. It is heated at its middle, necked-in, divided into halves, the inner and opposing ends of these halves bottomed and then the outer ends formed into the ordinary lip or a screw neck.

Automatic take-off device for glass-blowing machines. H. C. FENTRESS. U. S. 1,336,028, April 6, 1920. Grab arms for the glass-blown articles are mounted upon a rotary table which rotates in synchronism with the rotary table upon which the articles are blown. As these tables rotate the newly blown articles are seized by the grab arms and transferred to any desired receiver.

Method of and apparatus for drawing glass. A. E. SPINASSE. U. S. 1,336,056, April 6, 1920. A hollow, fluid-cooled drawing ring is immersed at the drawing surface and the cylinder drawn from the space enclosed thereby. The size of cylinder may be regulated by degree of immersion and cooling of the ring which in turn determines the area of glass which is chilled and rendered viscous.

Transfer mechanism for fruit-jar machines. U. S. 1,336,317, April 6, 1920. In making glass fruit jars the iron ring with the glass attached is transferred from the press table to the blow table when the jars are formed by the blowing apparatus. The transferring means consists of an arm provided with hooks for engaging the iron rings. These hooks are replaced by electromagnets according to this invention.

Burner for fire-polishing glassware. J. M. SAID. U. S. 1,337,328, April 20, 1920. This is a burner designed for fire-polishing glassware on the press

and before removal from the molds. The flame is given a swirling motion which completely envelopes the work.

Glass shaping and blowing machine. E. ROIRANT. U. S. 1,337,723, April 20, 1920. The parison, neck and finishing molds of this machine have opening and closing movements only and none of translation. Molten glass is drawn up through the bottom of the parison mold from a movable container. The bottom mold is then raised to support the parison, the parison mold is opened and the halves of the finishing mold swung into place. Thereupon the bottle is blown. Then the finishing mold is opened and the bottom mold descends bearing the bottle.

G. E. MIDDLETON.

Whiteware and Porcelain

On the elastic modulus of glazes. WALTER STEGER. *Keram. Rdsch.*, 27, 313-6 (1919); *Chem. Ztblt.*, No. 7, 1920.—The elastic modulus and thermal coefficient of expansion for 11 glazes was determined between room temp. and 100°. The values for the former lie between 5730 and 6830 /qmm. Glazes containing Pb have lower moduli than Pb free glazes. The modulus of normal Pb glazes is more strictly dependent upon chemical compn. than in the case of Pb-free glazes. The values obtained exhibit considerable differences from the constants determined by Winkelmann-Schott and from these observations it cannot be established whether there is a relation between the elastic modulus of a glaze and its compn.

H. G. SCHURECHT.

The dust question in the porcelain industry. F. KOELSCH. *Sprechsaal*, 53, 147-9, 155-7 (1920).—It has been found that the dust in porcelain factories has in many cases caused tuberculosis and catarrhal diseases. The analyses of the dust in various parts of a porcelain factory showed 83-266 mg. of dust in 1 cm. of air. The following remedies are suggested for reducing the dust evil: (1) Enclosing those parts causing the most dust from the rest of the factory; (2) removing the dust by suction; (3) frequent sprinkling of the floors to settle the dust; (4) employees should change clothes often and (5) the employees working in dusty rooms should have short hours and overtime should be forbidden.

H. G. SCHURECHT.

Defective ware in the casting of porcelain. O. ROSE. *Sprechsaal*, 53, 155 (1920).—Some of the common troubles with cast porcelain are uneven and warped surfaces. The trouble may often be traced to grinding the body too fine or to adding too much soda to the slip. One course of error often overlooked is the plaster mold which should absorb the water uniformly from the slip. In making molds the plaster should be constantly stirred until it thickens to prevent lumps of plaster having a different density than the rest of material.

H. G. SCHURECHT.

Cooking wares. K. ELEOD. *Pottery Gaz.*, 45, 510 (1920).—In the Sept. No. of *Ceramique* a recipe for a cooking ware body is given as follows: (1) China clay (kaolin) of Planards, by Saint Vallier; (1) china clay (kaolin)

of Dieulefit (Drome); (1) China clay of Auberives (Isere). The ware is biscuited at cone 08. The ware is covered with a thin coat of water glass before dipping into a fritted glaze which consists of borax 30; boric acid 20; pure flint 5; porcelain glaze 15; whiting 30 and matures at cone 02. The above was tried with Eng. china clay but it was found necessary to fire the biscuit to a higher temp.

H. G. SCHURECHT.

English china clay for hard porcelains. ANON. *Pottery Gaz.*, **45**, 513 (1920).—Rieke (*Sprech.*, **1915**, 21-3) and Mellor are extensively quoted. R. found that Eng. china clay contains less fine material than the other kaolins tested. It also contains less $\text{TiO}_2 + \text{Fe}_2\text{O}_3$ and has a whiter color than most clays.

H. G. SCHURECHT.

Dry grinding versus wet grinding. K. ELEOD. *Pottery Gaz.*, **45**, 510 (1920).—The non-plastic materials in Amer. earthenware bodies are ground too coarse. Dry grinding is better than wet grinding and cylinder grinding is more economical than pan grinding. The elutriation test does not classify the extremely fine material and, therefore, is merely a measurement of the coarseness rather than the fineness.

H. G. SCHURECHT.

Lime in earthenware bodies. A. HEATH AND A. LEESE. *Pottery Gaz.*, **45**, 502-3 (1920).—To determine if the use of lime in earthenware bodies causes crazing of the glaze, bodies of the composition ball clay 30, china clay 25, flint 30, and stone 15 were tested in which the stone was replaced by varying percentages of lime. The trials showed no signs of crazing after two years. A body of the composition ball clay 30, china clay 25, flint 30, stone 8.25 and whiting 6.75 was then tried and glazed with a factory glaze and it was found that the trials crazed badly. A fritted lead glaze was then tried and it gave better results on the porous bisque pieces while the glazes on hard fired trial pieces again crazed badly. By increasing the alumina, silica and boric acid a glaze was developed which did not craze on the hard fired bisque pieces but the maturing temp. was too high practice. By the use of this special glaze good results were obtained with bodies containing as high as 15 per cent whiting.

H. G. SCHURECHT.

The china clay industry of west England. H. F. COLLINS. *The Mining Magazine*, **21**, 269-75, 329-37 (1919); **22**, 25-32, 94-7 (1920).—Although deposits of china clay and china stone occur in several areas in the west of England, the Hensbarrow district, north of St. Austell is the principal producing area. The occurrence, origin and form of the deposits are discussed. Much space is given to methods of mining, purification, preparation for market, and uses of the materials. Analyses, tables of production, photographs and tabulated body formulae are included. The conditions of the industry are dealt with at some length.

E. D. ELSTON.

White earth, its competition with China clay. ANON. *Brit. Clayworker*, **29**, 18-9 (1920).—Owing to the increased price of china clay, the competition

of white clays such as are found in America, France and Germany is becoming keener. Some merits claimed for the English china clay are as follows: They are extremely fine grained as most washed china clays will easily pass a 120-mesh sieve. Owing to its freedom from potash it makes an excellent material for porcelain. The increased use of china clay for sizing of cotton goods is due to its adhesiveness and weight, which are given to a size of flour and clay. These advantages are not attainable to the same extent with other materials. Its use in paper is becoming increasingly popular with paper manufacturers as loader and filler, because it not only effectively fills up the interstices between the fibers of the pulp, but is readily incorporated with the fiber, and adheres so tenaciously to it that vigorous teasing in water will not separate it. It is also stated that china clay has a greater affinity for printers ink than any other material used for filling purposes.

H. G. SCHURECHT.

Various problems in the porcelain industry. F. SINGER. *Dingler's polytech. J.*, 9, 96-101 (1920).—Glazes for chemical porcelain were made more resistant to chemical reagents by increasing the silica and alumina contents. In high tension porcelain insulators it was found that the coeff. of expans. of the porcelain was 0.00000379 and that of the cement 0.00001100. This difference in expans. cracked many insulators and a cement having a lower coeff. of expans. was developed. During the war substitutes for English kaolins and ceramic colors were developed. New uses for ceramic materials were introduced, namely, door latches, window clasps, weights, mortar, lamp stands, and so forth. Normal porcelains have a softening point of 1500° C and special porcelains at 1700° C. Marquardt bodies have a softening point of 1850° C and are not considered porcelains because they do not become dense, transparent and white. Other materials which have a high softening point are: alumina 2050° C; silicon carbide, 2500° C, magnesia, 2800° C, zirconium oxide, 2950° C, and boron nitride, over 3000° C. These are not considered porcelains, however, since they do not become dense and transparent when fired at normal temperatures.

H. G. SCHURECHT.

Pottery making in Japan. J. F. ABBOTT. *Clay Worker*, 1920, 596-7, 646.—Japanese pottery may be divided into three classes (1) stoneware in which ornaments are put on the ware by stamping or scoring; (2) faience which has a crackled glaze and is highly decorated. It is not fired as high as porcelain and for this reason may be decorated with more delicate colors, and (3) hard porcelain and semi-porcelain. Kaolin is washed in horizontal washing machines consisting of a barrel-shaped tub filled with water, about 12 ft. long and 6 ft. in diam. Within this barrel is a revolving horizontal shaft to which arms are attached. Sand is deposited in the washer and the finer material is passed through troughs which branches into more troughs, thus decreasing the flow of the slip and allowing the mica and other impurities to settle. The old style glazes are compounded of clay paste with wood ashes of oak and chestnut. The bulk of the Japanese ware is made

in the household, one family making the molds while another does the casting, and so forth. The kilns are usually placed along a hillside, the successive kilns being placed at higher levels than the preceding ones. The heat from one kiln passes through those above operating somewhat like the German Hoffmann kiln.

H. G. SCHURECHT.

PATENTS

Casting of pottery and other like articles. B. J. ALLEN AND R. Y. AMES. U. S. 1,336,180, Apr. 6, 1920. Slip casting in porous molds is expedited by surrounding the mold with an enclosed space and reducing the pressure within this space. The water in the slip is thus more quickly drawn through the porous mold. The same result may be produced by introducing the slip under pressure. Walls of varying thickness may be made by varying the thickness of the mold walls, the thinner the mold wall the more rapid the flow of water through it and consequently the greater the thickness of the clay wall which builds up at this point. Large, thick articles such as glass-house pots, retorts, crucibles and the like may be made by this method.

Method of staining glazed ceramic ware. J. W. HASBURG. U. S., 1,334,301, Mar. 23, 1920. When it is desired to stain glazed ware, the glaze of which is unsuitable for fire staining, a secondary glaze which is suitable is applied and fired. The stain is applied to the secondary glaze and fired in the usual way.

Method of making sanitary earthenware. E. H. LAWRENCE. U. S. 1,337,663, Apr. 20, 1920. It is a common practice in making closet bowls by slip-casting to cast the bowl and cut away certain parts of the mold to form passageways. According to this invention those parts of the mold corresponding with the passageways are coated with shellac to make them non-absorbent, with the consequence that the slip does not deposit and form a wall at these places.

Method and means for producing saggars. F. J. WOLFF. U. S. 1,337,871, Apr. 20, 1920. The sagger body is expressed in sheet form through a die having the width and thickness desired in the slab produced. This die is lubricated by means of a series of small pipes radially disposed about the condensing nozzle and projecting slightly into the clay, forming grooves. The lubricant is fed into these grooves through the small pipes. The ribbon emerging from the die is cut into desired lengths and made into saggars. A better distribution of the grog is said to result from this method than can be obtained from other machine methods of forming saggars.

G. E. MIDDLETON.

Enamels

Composition of enamels for cast iron. Schnurpfel's review for glass works. Vol. 3, No. 35, p. 549.

| | White | White | Blue | Blue |
|-------------------|-------|-------|------|------|
| Feldspar..... | 40 | 42 | 46 | 25 |
| Borax..... | 28 | 22 | 21 | 30 |
| Soda ash..... | 10 | 13 | 14 | 11 |
| Tin oxide..... | 8 | 8 | ... | 2 |
| Saltpectre..... | 1 | .. | 2 | 3 |
| Fluorspar..... | .. | 5 | 4 | .. |
| Cobalt oxide..... | .. | .. | 1.75 | 2 |
| Quartz..... | .. | .. | ... | 17 |
| Cryolite..... | .. | .. | ... | 3 |

R. J. MONTGOMERY.

Enamel investigations at the Bureau of Standards. STAFF ARTICLE. *Chem. Met. Eng.*, **22**, 810 (1920).—At the request of the Metalware Manufacturers Association of America, the Enameled Metal Division of the American Ceramic Society and a large number of individual manufacturers, the Bureau of Standards is carrying on a comprehensive research in an endeavor to discover the cause or causes of the jumping off of small particles of enamel, which results in the defect known in shop practice as "fish scaling," and the methods of controlling and eliminating it. This investigation was begun in July, 1919, and has been conducted energetically ever since. For several months the Bureau has had in progress an investigation of the relation of composition of enamel to solubility in strong mineral acids. Results so far obtained indicate that some of the commonly accepted conceptions of the relation between composition and acid resistance of enamels are erroneous. Information is being secured, also, in regard to relations of composition to fusibility and to the tendency to chip or to craze, or crack.

A. J. LAMBERT.

Papers on enameling before the Chicago Section, American Ceramic Society. STAFF ARTICLE. *Chem. Met. Eng.*, **22**, 1107 (1920). See *J. Am. Ceram. Soc.* **3**, 522 (1920).

A. J. LAMBERT.

PATENTS

Enameling and annealing furnace. P. DUPONT. U. S. 1,335,279, Mar. 30, 1920. The furnace described is particularly designed for the enameling of bath tubs, although it may be modified in shape to be suitable for other articles. It comprises a receptacle conforming in shape to that of a bath tub, the walls of which are lined with a porous refractory. A cover of similar material is provided. A mixture of fuel gas and oxygen is forced through the porous walls and ignited. These walls thus become incandescent and impart their heat to the tub. When the proper temperature has been reached the cover is removed and the enamel sprinkled over the surface of the tub. As the tub is meanwhile being subjected to the furnace heat the powdering can be effected in one operation.

Process for permanently producing picture effects upon enameled metal surfaces. R. SANDBY. U. S. 1,335,755, Apr. 6, 1920. After the enameled

surface to be treated is cleaned, it is coated with a uniform coat of a suitable gum varnish. After the varnish has set the picture is transferred upon it. This is done by first printing the matter to be transferred on transfer paper with printers ink, dusting it evenly with a mixture of metallic oxide and silica and pressing the inked and coated paper upon the varnished surface. The paper is then removed and after the coated surface has dried it is dusted with a low-fusing flux. The whole is then fired. G. E. MIDDLETON.

Brick and Tile

Slag brick. ANON. *Tonind.-Ztg.*, 44, 582-3 (1920).—Near Berlin alone there are four plants making brick from gaswork slag, which seems well adapted for this purpose. The slag in this vicinity is very hard. The sulphur content in the slag should not be too high and this may often be reduced by certain refining treatments. The slag is crushed to 12 mm. size. At first a mixture of 1:8 was used with cement as a bond, but since 1:10 mixtures have a crushing strength of 35-40 kg./cm., which is amply strong enough for many purposes, this mixture is now used almost exclusively. The batch is thoroughly mixed with water for about 5 mins., when it is fed into molds of a Nestor machine. Each brick receives 5 blows from an electrically driven hammer and 6 brick are made at once. At the end of 14 days they are ready for use. Each slag brick machine makes 500 brick per hour. With 6 machines operating 8 hrs. 22-2400 brick can be made per day using a 16 h. p. motor. H. G. SCHURECHT.

Brick sands. ANON. *Tonind.-Ztg.*, 44, 529 (1920).—Many so-called brick clays are nothing but sand bonded together with clay. The chemical analysis of 7 materials used for making brick showed that the content of silica in these are as follows: (1) 32.80 per cent, (2) 35.8 per cent, (3) 41.00 per cent, (4) 43.20 per cent, (5) 49.90 per cent, (6) 57.80 per cent, (7) 72.18 per cent. A good many of these should be more properly called sands rather than clays. H. G. SCHURECHT.

Compression strength of loam brick and loam brick masonry. GEBAUER. *Tonind.-Ztg.*, 44, 301-3 (1920).—Owing to the shortage of coal in Germany a large number of clay brick are used in the unburned state. To compare these brick with fired brick compression strength tests were run on air dried specimens and also on masonry consisting of three to eight brick placed upon each other to form a column. The following results were obtained:

| Manner of making | Compression strength, kg./cm. ² | After 4 weeks storage in contact with moist air | |
|------------------|--|---|--|
| | | Water absorption, per cent | Compression strength, kg./cm. ² |
| Machine..... | 42.3 | 1.09 | 27.2 |
| Machine..... | 34.9 | 1.02 | 21.1 |
| Hand..... | 30.9 | 1.12 | 21.3 |
| Hand..... | 26.1 | 0.76 | 20.1 |

Tests made on columns of three brick gave compression strengths varying from 9.0 to 37.1 kg./cm². First class fired clay brick must have a compression strength of 150 kg./cm², and second class brick must have a compression strength of 100 kg./cm². It is, therefore, obvious that the unfired brick do not meet these requirements and, therefore, should only be used to support light loads. When in contact with damp soil and rain the brick readily disintegrate and, therefore, must be protected from these sources of moisture. Since the cost of the brick is only a small part of the total cost of a house the saving due to using unburned brick is very small. After the coal again becomes plentiful it is predicted that burned brick will take the place of the unburned brick.

H. G. SCHURECHT.

Bricks, preventable defects in refractory. C. E. NESBITT AND M. L. BELL. *Proc. Am. Soc. Testing Materials*, 19, Part II, 620-9; see *J. Am. Ceram. Soc.* 3, 330 (1920).

A. J. LAMBERT.

PATENTS

Method and means for setting brick mechanically in kilns and the like. W. W. DICKSON, JR. U. S. 1,334,892, Mar. 23, 1920. This invention relates to a device for setting bricks mechanically. The brick to be set are placed upon a pallet, the pallet lifted by a metallic support carried by a traveling crane and moved to the spot where the bricks are to be set. The pallet and its support are then tipped and withdrawn allowing the bricks to slide off into position.

Brick machine. O. J. MOUSETTE. U. S. 1,335,071, Mar. 30, 1920. This is a type of machine which comprises an intermittently rotated mold table, a plunger for compressing the material in the molds, an endless carrier in feeding pallets into position for receiving the bricks and delivering them from the machine, and an ejector for dislodging the bricks from the molds.

Brick-handling and setting apparatus. G. E. LUCE. U. S. 1,335,344, Mar. 30, 1920. This invention relates to a machine for handling green, dry and burned brick in a pile or unit stacked relation. One of the improvements relates to means for setting the benches between the arches of a kiln.

G. E. MIDDLETON.

Abrasives

PATENTS

Abrasive wheel. S. C. LINBARGER. U. S. 1,336,751, Apr. 13, 1920. In order to obviate the radial cracking which often occurs around the arbor hole of abrasive wheels, that part of the wheel adjacent the arbor hole is made less dense than other parts of the wheel. The same bond is used throughout, but the central part of the wheel is made less dense by the use of a greater percentage of coarser abrasive grains in the central portion.

G. E. MIDDLETON.

Cement and Lime

Enemies of cement. ANON. *Tonind.-Ztg.*, **44**, 593 (1920).—The destructive agents occurring in cement are uncombined lime, magnesia, and gypsum. In cements made from blast furnace slags manganese and sulphides often cause trouble. Destructive agents which attack the cement from the outside are acid waters, magnesia salts in sea water, sulphuric acid of swamps, carbonic acid in water and certain fatty oils which penetrate the cement and form lime soaps with the lime thereby destroying the cement.

Heretofore remedies for all these evils with the exception of the oil have been used successfully. A cure for the oil trouble has been recently developed by a German concern which has proved very successful.

H. G. SCHURECHT.

Iron cement ships. ANON. *Tonind.-Ztg.*, **44**, 344 (1920).—Ships of cement have been built in Norway and Sweden. These ships behave satisfactory in storms with the exception that water is thrown over the low free board line. By the use of light weight aggregates the density of the concrete may be decreased from 2100 kg. to 1500 kg./cm³. which would raise the free board line higher above the water. A cement ship "Askelad" was recently stranded upon St. Quentin. After pumping out the water the ship was all right with the exception of the loss of some machinery. An iron ship was stranded here and wrecked, showing that cement ships can withstand rougher treatment than the iron ships.

H. G. SCHURECHT.

Cement balls for ball mills. ANON. *Tonind.-Ztg.*, **44**, 411 (1920).—Pieces of cement clinker were broken to sizes slightly larger than pebbles used in ball mills. They were then put in the mills together with a charge and after grinding became smooth, making excellent substitutes for flint pebbles.

H. G. SCHURECHT.

Bricks for lining rotary kilns. ANON. *Brit. Clayworker*, **29**, 9 (1920).—In rotary kilns used for firing cement there are three zones in which it is desirable to employ different classes of brick. The first or charging zone should be very resistant to abrasion but a high degree of refractoriness is not necessary. The second or fluxing zone is subjected to the high temps. and should be lined with aluminous material containing not less than 35 per cent alumina and having a softening point of at least cone 32. Bricks made of fused alumina give best results in this zone. To prevent heat losses the lining should be surrounded by a porous insulating brick. A mixture of burned cement and raw cement are sometimes used in the place of brick. Magnesite brick are too sensitive to sudden temp. changes and chrome brick are too expensive. Carbon brick can not be used because of the oxidizing atmosphere. Silica and carborundum brick are destroyed too quickly by the action of cement. For the third or cooling zone, brick which are very re-

sistent to sudden temp. change should be used. Fire-clay brick rich in alumina and being dense are desirable.

H. G. SCHURECHT.

Cement in 1918. E. F. BURCHARD, *et al.* U. S. G. S. *Min. Res.*, 1918, Pt. II: 25, Apr. 9, 1920. Interesting data and tables of statistics covering the domestic and foreign cement industry are given in this report.

E. D. ELSTON.

Process for manufacturing of insulating bodies from basic magnesium-carbonate and fibers. Ger. pats. 303,310 issued 8/11/19 and 304,239, C, 1920, Lipsia Chemical Works.—Basic magnesium carbonate is precipitated from solution on mineral, vegetable or animal fibers. The magnesium sol. is filtered through the form and allowed to impregnate same. It is advantageous to carry out the process in two stages by first precipitating magnesium carbonate and after decanting the mother liquor transforming the precipitate into basic magnesium carbonate by boiling with water. Shapes so produced are much lighter than those obtained by pressing in a form.

H. G. SCHURECHT.

PATENT

Cement. G. WITTY. U. S. 1,336,178, Apr. 6, 1920. A cement composition consisting of clay, finely divided rock, yellow dextrin, barium sulphate and barite.

Artificial stone for roofing. C. B. AYERS. U. S. 1,335,038, Mar. 30, 1920. A composition comprising lime, asbestos fiber, soapstone and silex adapted to be made into sheets.

ACTIVITIES OF THE SOCIETY

New Members Received during May

Associate

- Brennan, George L.**, 5 N. Carey St., Baltimore, Md., Supt., Chesapeake Terra Cotta Co.
- Castro Oliveira, Rodolfo**, Box 188, Alfred, N. Y., Student, New York State School of Ceramics.
- Crownover, A. W.**, Factory Manager, Maryland Glass Corporation, Mount Winans, Md.
- Donahoe, Frederic W.**, 840 Oliver Bldg., Pittsburgh, Pa., Secretary, The Refractories Manufacturers Association.
- Hartford, Frank M.**, Box 145, Abingdon, Ill., Supt., Kiln Construction, Abingdon Sanitary Mfg. Co.
- Hodges, R. T.**, 303 Railway Exchange, Chicago, Ill., Magnus Co.
- Huisken, H. A.**, 6720 St. Lawrence Ave., Chicago, Ill., Student, University of Illinois.
- Inman, G. E.**, Development Engineer, Lamp Development Laboratory, Nela Park, Cleveland, Ohio.
- Lindmueller, Charles**, Supt., Metal & Thermit Corporation, East Chicago, Ind.
- Ogden, D. P.**, Engineer, Streator Brick Co., Streator, Ill.
- Robinson, J. D.**, President, Libbey Glass Mfg. Co., Toledo, Ohio.
- Stockdale, V. B.**, 609 W. Meek St., Abingdon, Ill., Supt. Abingdon Sanitary Mfg. Co.
- Tyler, H. B.**, 216 Gibson St., Canandaigua, N. Y., Supt., Enamel Department, Lisk Mfg. Co.

Foreign Associate

- Laird, Clinton N.**, Professor of Chemistry, Canton Christian College, Canton, China.
- Mackie, I. C.**, Dominion Iron & Steel Co., Sydney, Nova Scotia.
- Satoh, Shinzo**, Engineer, Tokio Electric Co., Kawasaki, Kanagawaken, Japan.

Corporation

- Bush, W. G., & Co.**, 174 Third Ave. North, Nashville, Tenn.

Important Actions of the Board of Trustees

June 9. It was voted to accept Mr. R. C. Purdy's resignation as chairman of the Committee on Sections and Divisions.

June 9. It was voted to authorize the chairman of the Committee on Publications to render expense accounts for postage, stenographic services,

and travel in soliciting advertisements for the Journal, the sum of not more than \$400.00 to cover such expenses up to the next annual meeting.

June 9. It was voted that the price of the Collective Index to the Transactions be one dollar.

June 22. It was voted that the Glass Division be asked to nominate a person who shall act as official representative of the American Ceramic Society and escort to the party from the Society of Glass Technology, of England, on their trip to glass plants in America, the expenses of such a representative to be paid by the American Ceramic Society.

Special Meeting of the Enamel Division at Washington, D. C., June 15, 16, 1920

The Enamel Division held a joint conference with the Sheet Metal Ware Manufacturers Association at the U. S. Bureau of Standards, Washington, D. C., on June 15 and 16. The results of the investigation on fish scaling of sheet steel enamels were presented at the meeting before forty-five representatives of various enameling firms and interests from all sections of the country. This was the first special meeting of the Division ever called and the attendance and the interest manifested were very gratifying.

Preceding the presentation of the report on the investigation of fish sealing two papers on enamels were read. These consisted of a paper on "Cast Iron Enameling" by H. L. Menne, and one on "The Preparation of Sheet Steel for Enameling" by L. G. Whitford. These papers were originally presented at a meeting of the Chicago Section.

A report of the meeting will be mailed at an early date to all members of the Division. It is the desire of Chairman Poste to hold a division meeting during the summer session in Chicago to bring out developments of the various investigations being conducted by members of the Division, and it is hoped that the attendance will equal that at this special session at Washington.

R. R. DANIELSON,

Secretary.

A Letter From the President

The following letter from Mr. Minton to the Secretary is thought to be so interesting that all the members of the Society should see it.

DUSSELDORF, GERMANY, June 10, 1920.

MY DEAR PROF. BINNS:

Have been trying for some time to get a letter off to you, but it seems I have little time left when my schedule is completed and I have written to my wife and sent out a few postcards.

I left Berlin last Monday A. M. and came through to Wesel. Was busy there in a plant until noon today, when I came to Dusseldorf. Tomorrow I spend in a plant at Rottingen near here. Saturday I go to Cologne, where I meet Carl Griffin and Bob Anderson of the Norton Co. Sunday I expect

to take the famous ride up the Rhine. On Monday I shall see the Norton plant and Tuesday leave for Leipzig where I shall spend a couple of days. Then on to Bau Elster, a bathing place, where I shall spend four or five days with friends. I then go to Dresden and Meissen, where I see some porcelain and sanitary plants. Then down to Selb to see the famous Rothenthal Porcelain Works, the largest in Germany. Expect also to see a plant making doll heads. Then go to Altwasser to see a new tunnel kiln and on to Münsterburg to see the largest sewer pipe plant in Germany. Then I go to Breslau and then on to Berlin. Have several one-day trips of inspection from Berlin and shall leave about July the tenth for England.

Have already visited a number of plants and have found some things of great interest. Have been especially interested in the plants making stove-tiles, something quite new to me. The Royal (now Staatlicher) Porcelain Works at Berlin was very interesting. Dr. Rieki, the director, was very much interested in getting our transactions from 1914 to 1920, as he was unable to get them from 1914 on. On account of the adverse rate of exchange it is impossible for the Germans to renew membership in the A. C. S. I have thought we might send Dr. Rieki a set in exchange for a complete file of Sprechsaal and Cheramischer Bund., which might be of value to our abstractors.

Conditions in Germany are very bad. As long as I am in the good hotels in the larger cities I can get all I need, although it is expensive. But in the smaller cities and towns the food is very bad and many things cannot be had. Two weeks ago I spent ten days down in a small town near Dresden and could not have stayed except for food I took along. Sugar, butter, milk, meat and fresh fruits simply could not be bought and the bread is almost uneatable. Today I had the only good bread I have had since coming into Germany. I am getting very tired of the poor food and lack of variety. Potatoes are about the only vegetable, although garden truck is now coming in. I have forgotten what a steak looks and tastes like.

All the ceramic plants are working as full as they can, but not up to production on account of lack of coal. I must confess I am not optimistic on the future of Germany. I do not see how they can continue to work and produce unless they have food. It would not surprise me to see Bolshevism in Eastern and Southern Germany this winter.

Traveling is very trying. The trains are all gone to pieces, the cars are dilapidated and dirty, and the tracks are uneven. Germany is surely all shot to pieces. They went until the last match was burned. I really do not see how the people could be made to endure the war so long. It seems to me that no other people would have done so.

Have heard nothing from America since I left, but I trust the A. C. S. matters are being pushed along well and that new members are coming in and advertisements are placed.

Give my regards to all members of the Board.

Sincerely yours,

(Signed) R. H. MINTON.

Necrology

George F. Young.—With the death of George F. Young, the American Ceramic Society and the ceramic industries of this country lost one of their most striking figures. Mr. Young was actively identified with the industrial life of Zanesville, Ohio, for nearly a quarter of a century. He was at the head of The Roseville Pottery Company, which from its incipiency was under his guidance. Beginning in a small way at Roseville, Ohio, he built up one of the greatest ceramic manufacturing concerns in Ohio, and at the time of his death was its manager and treasurer. Many years ago the business was moved to Zanesville and a consolidation of all its subsidiaries effected.

Mr. Young was a man of tireless energy, keen perception, and steadfast adherence to purpose. He was a genius in the matter of detail, and up until the very last kept in close touch with his business, which will be a lasting monument to his ability and energy.

Plans for Summer Meeting

Plans for the Summer Meeting are rapidly materializing. The meeting will occur in Chicago and the dates will be August 16-18 both inclusive. Headquarters will be at the Hotel La Salle, and the following plants will probably be visited: The Northwestern Terra Cotta Company, The Bach Brick Company, The Lindsay Light Company, The Coonley Manufacturing Company, The Western Electric Company, and the Fansteel Products Company. Others will be added to the list. The programs will be issued in good time. Fred B. Ortman, Northwestern Terra Cotta Company, is chairman of the Summer Meeting Committee.

Plans for Ceramic Day at the Exposition of Chemical Industries are also maturing. Friday, September 24th, has been selected as the day. The program is in the hands of the Committee on Coöperation. Mr. H. Schmidt, Roessler and Hasslacher Chemical Company, is chairman of the local committee.

Meeting of the New England Section

A meeting was held in Worcester, Mass., June 12, 1920. During the afternoon an inspection was made of a fine collection of early American pottery. Dinner was served at the Norton Boat Club and eighteen members were in attendance.

A paper on "Fuel Oil Burners for Tank Glass Furnaces" was given by Mr. Browne Harding of the Providence Base Works of the General Electric Co. This was very interesting and was followed by quite a general discussion.

M. C. BOOZE, *Secretary*

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EDITORIAL

WORKING ON A SALARY

The trouble about working on a salary is that you do not discover it is not the road to success until it is too late to change.

It is a rather remarkable circumstance that very few of the graduates from the ceramic schools of this country have engaged in business for themselves. In part, this is due to the fact that the bulk of these men are still recent graduates. However, there are quite a number of graduates of ten and fifteen years standing, and a few that have been out of college for twenty years. The trouble seems to be that while in college they were trained to think of success in terms of salaries. College professors, being themselves salaried men, are naturally inclined to measure success in that way. You may send a boy to school for technical training, but while there he will absorb from his instructors many other things, including ideas and ideals in regard to life. In many respects this is very desirable, and in others it is quite unfortunate.

The young man leaving college naturally starts to work on a salary. On receiving his first or second raise he marries and begins the serious business of establishing a home and founding a family. As the years go on his salary increases and his expenses also. Since he is always able to meet expenses and in addition to keep up some life insurance and probably to make

small but regular payments on a home, he is usually very well satisfied with the course of events for some ten or fifteen years. Along about the time he reaches the age of forty he is apt to realize rather suddenly that he is not getting ahead as fast as men of his own age who started in business for themselves in a small way when young. He sees many of these men on the road to making fortunes and regretfully is forced to the conclusion that he will never be able to do so while working on a salary.

For a man in middle life nothing is easier than to continue to work at a good salary. It takes considerable courage and often the exercise of a large amount of self-denial, on the part of himself and his family, for him to give up his comfortable salaried position and to start into business for himself. In general, it would be necessary for him to start in a very small way, for during the years he has been working on a salary, although his income may have been as large, or larger, than that of the man in business for himself, yet as a salaried man he has not had the same incentive to save, and therefore has accumulated little capital. Usually, with a sigh of regret for what might have been, he reconciles himself to the prospect of being a salaried man the rest of his life and pretends he likes it. The difference between the successful business man and the middle-aged man on a salary is not a difference in native ability and seldom a difference in opportunity. Generally it lies in the fact that the one had a fixed determination to get into business for himself and acted on that determination while he was a young man and in a position to take a chance.

We are not saying that the technical man of ability that enables him to hold a position at a good salary, year in and year out, has not attained a measure of success. We are not saying that he is not a desirable and useful citizen. We do hold, however, that in most cases he has not attained the full development of personality and character that would have been possible if he had gone into business for himself. In general, he is fundamentally not as happy and contented, for the desire to possess an independent business is one of the primary instincts of men. The difference in wealth is incidental only. The truly successful business man takes pride in his possessions only in that they

are an evidence that he has played his part in a big and dangerous game, and played it well.

We believe that it will be to the advantage of the ceramic industries of this county, even from the technical side, if the young men with technical training are urged to aim high, to set as their goal not the attainment of a position paying a high salary but the possession of a business of their own. If this is done a fair proportion of these men will reach this goal and will then be in a position to put into practical operation many of the reforms in technical procedure that even now remain idle dreams, simply because the men who realize the necessity for these reforms are not in a position to execute them. At present most of the technical knowledge is in possession of one set of men, and most of the executive power and capital is in the possession of another group. This condition does not tend to bring about rapid progress along technical lines in the ceramic industries of the country.

ORIGINAL PAPERS AND DISCUSSIONS

ULTRAMISCROSCOPIC EXAMINATION OF SOME CLAYS¹

BY JEROME ALEXANDER

Prior to the World War, the United States had been largely dependent upon Germany and Austria for its supply of optical glass and many of the scientific and optical instruments which comprise optical glass in their construction; so that when this country was forced into the struggle, it was imperative that we should discover and put into practical operation on a large scale methods for producing about a dozen essential varieties of optical glass. How this work was speedily and successfully accomplished has been told by Dr. Arthur L. Day, of the Geophysical Laboratory (Carnegie Institution of Washington), who was in charge of the Section of Optical Glass Production, War Industries Board.

One of the subsidiary problems involved was the manufacture of suitable glass-pots; and in this connection it became necessary to substitute American clays for German clay which had been in use before the war. This led Dr. Day to raise the question whether a more fundamental definition of properties could not be found; and on November 24, 1917, there were sent the writer (who was then Chairman of the Sub-committee on Glue and other Colloids, Division of Chemistry, National Research Council), eleven samples of clay, which were subjected to ultramicroscopic examination with a view of finding out whether any material differences would be discernible, and if so, whether the differences would bear any relation to the working properties of the clays.

¹Received February 27, 1920.

A small quantity of clay was mixed with about two hundred times its weight of water, and a drop of the well stirred mixture made into a slide and examined with the aid of a Leitz dark-field, using a $\frac{1}{12}$ oil immersion objective. This examination was preliminary and qualitative; but, as may be seen from the accompanying table, it showed very marked differences between the several clays, and indicated the basis of some of the physical differences in clays.

In April, 1918, further examination was made of the same clays which had been washed or lixiviated with water and then allowed to settle for nine minutes, the second samples representing what had then been poured off with the supernatant fluid. The results of this second examination are given following the table. The examinations were made in total ignorance of information regarding the working properties and uses of the clays; and it is therefore interesting to note how this information, received about a year later, harmonizes with the results.

Both examinations were repeated in the presence of Dr. Day and the results discussed with him; but following the armistice, work on optical glass problems ceased abruptly. Just recently Mr. A. V. Bleining of the Bureau of Standards, who had supplied the samples, has kindly given me a description of the clays and their working properties; and these facts coupled with the ultramicroscopic results may be of value to those interested in clays and their uses.

The properties of clays are, of course, greatly influenced by their chemical constitution (which changes with the presence of incidental minerals); but entirely apart from this, the degree of subdivision or aggregation of the clay particles has an important influence on the clay and its uses. Water is the chief agency responsible for the weathering of the clay-forming minerals and rocks, and for the subsequent leaching, disintegration, mechanical pulverization and segregation of the resulting clay particles, whose subsequent condition is largely controlled by two colloid-chemical factors: (1) The presence of deflocculating substances, such as alkalis and organic extractives (humus, etc.); (2) the presence of coagulating or flocculating substances, such as chlor-

ides, sulphates, iron salts, acids resulting from oxidation, hydrolysis, differential diffusion, etc.

Apparently deflocculating substances are adsorbed at the surfaces of the clay particles, resulting in their greater hydration. Such surfaces not only tend to hold more water, but are more easily wet, and more readily separated; the water or moisture films, or films of moist deflocculator, prevent the particles from approaching within the most powerful range of molecular attraction. Baking removes or destroys these protecting films, and consolidates the particles; the degree of their union depending upon time and temperature of heating. In like manner gelatine superdried at about 150 degrees C becomes insoluble, apparently reverting to ossein.¹

Coagulating substances, heat and pressure have an aggregating and dehydrating tendency. They tend to reduce the total free or active surface of the clay. But in most clays there is a balance between flocculating and deflocculating factors, and their interplay controls the ratio between pore water and shrinkage water, and is largely responsible for the physical properties of the clay.

In fact each clay as it occurs in nature bears within itself much evidence of its geological history, the chemical and mechanical disintegration processes of past ages; lixiviation by glacial or other waters; subsequent sedimentation in still lakes or flats, or coagulation by saline waters; leaching out of some salts or soluble products; infiltration of other salts and of organic extractives; pressure of overlying strata; thermal changes due to solar heat, volcanic action, or metamorphic movements of the earth's crust which also cause pressure. All these factors which have acted on clays as we find them, and offer a wide field for careful scientific study, so that we may learn how to test, treat and mix clays to produce the practical results desired; for once we understand the principles governing the properties of clays, we can work upon them with substances much more powerful than those found in nature.

Many clays undergo washing or other treatment at the mines

¹ See Allen's commercial organic analysis, 4th ed. 8, 586.

or pits, and may differ materially from the clay as mined. This must, of course, be taken into consideration in forming opinions regarding the commercial product.

With reference to the table, some explanation of the terms and abbreviations used is essential.

Large particles are those approximating in actual diameter about 0.025 mm.

Small particles are those approximating in actual diameter about 0.005 mm.

Colloidal particles are those below the limit of microscopic resolvability. Their relative size was estimated on the basis of the brightness of their diffraction images and the nature of their motion.

The appearance referred to as *reticulated*, indicates that the larger particles so described were formed of smaller individuals united by coagulation, dehydration, heat, or pressure, or some combination of these.

The expression *gel groups* or *gel particles*, means the occurrence of somewhat more loosely bound groups of particles, similar in appearance to, though larger than, the groups of ultramicros observable in agar gel.

The term *hampered* in connection with the motion of the colloidal particles, means that they acted as though some crystalloid salt or other coagulant was present. In several of the samples this effect was so pronounced that a separate column was made headed "crystalloidisis," to bring out this point.

++ means marked crystalloidisis.

+++ means very marked crystalloidisis.

The expression *diplococci* indicates the presence of groups of two (or three) ultramicros, an appearance characteristic of the incipient coagulation of colloids like casein, for example.

In the case of the clays there seems to be a balance between the flocculating and deflocculating forces, depending upon their nature, the amounts present, the dilution, the age of solution, and so forth.

ULTRAMICROSCOPIC EXAMINATION

MIXED WITH EQUAL WEIGHT OF WATER

| No. | Description of Sample | PARTICLES | | | Colloidal motion | Crystall-oidis | Order of acidity to litmus | Mixed with water | Feel | Appearance |
|-----|---|--|-----------------|----------------|-----------------------------|----------------|----------------------------|--------------------------------|------------------------|---------------------|
| | | Large | Small | Colloidal | | | | | | |
| 1. | English kaolin | Few, reticulated | Few | Many | Very active | | 1 | Easy | Smooth | Moist cream |
| 2. | Georgia kaolin | More than (1)—not reticulated | Many | Fewer than (1) | Slow, | | 1 | More difficult than (1) | Smooth | Moist cream |
| 3. | Florida kaolin | Fewer than (2)—reticulated | Fewer than (2) | More like (1) | Active—not as active as (1) | comparatively | 2 | Easy | Less smooth than (2) | Drier cream |
| 4. | North Carolina kaolin | Many—some very large, some yellow with adsorbed Fe | Many | Many (large) | Slow | | 2 | Easy | Rough | Drier than (3) |
| 5. | Tennessee ball clay No. 5 | Few | Many | Many | Very slow | ++ | 3 | Very easy | Smooth and sticky | Wet |
| 6. | Kentucky ball clay No. 4 | Many very large gel particles | Few | Small | Hampered | +++ | 4 | More difficult than (5) | Stickier than (5) | Drier than (5) |
| 7. | Illinois Kaolin Co. plastic clay | Practically none | Many gel groups | Many | Hampered | | 3 | More difficult than (1) or (5) | Very smooth and sticky | Dry |
| 8. | Highland fire clay | Many—huge masses | Many | Large | Slow | | 3 | Easy | Gritty | Wet—free water |
| 9. | Laclede-Christy bond clay 69B | Practically none | Many | Small | Very active | | 5 | Easy | | Very wet—free water |
| 10. | Plastic clay Camden, Ark. | Many—mostly sharp crystals | Many | Large | Slow | ++ | 4 | Easy | Harsh | Wet |
| 11. | Delaware kaolin Newark Kaolin Co. and reticulated | Some—mostly gel | Few | Small | Hampered | +++ | 2 | Easy | Smooth but harsh | Wet—free water |

The following notes were made after second ultramicroscopic examination, the samples being the same as before, except that they had been "decanted after nine minutes."

Sample (1). English China Clay. Same as first report. Easily breaks up in water.

Sample (2). Georgia Kaolin. Particles much larger than (1). Show indistinct reticulation and appear in large masses. Practically no motion in the upper layers of the field. Small particles motionless at the bottom.

Sample (3). Florida Kaolin. Mostly large reticulated masses. Few small particles very active, but none as active as (1).

Sample (4). North Carolina Kaolin. Same as first report. Colloidal motion more active.

Sample (5). Tennessee Ball Clay No. 5. Same as first report. Colloidal motion more active.

Sample (6). Kentucky Ball Clay No. 4. Same as first report. Colloidal motion much more active. Subdivision greater than (5).

Sample (7). Illinois Kaolin (sample so marked). Motion hampered. Particles apparently large. Many large reticulated gel groups. Numerous diplococci.

Sample (8). Highland Fire Clay. Particles so large as to be mostly microscopic. Colloidal particles relatively few, slow in motion.

Sample (9). Missing. (Laclede-Christy Bond Clay 69B).

Sample (10). Arkansas Fire Clay (sample so marked). Many large crystal fragments. Colloidal particles comparatively few with slow and hampered movement. As a rough estimate about $\frac{2}{3}$ of the particles by weight are quite large, and $\frac{1}{3}$ quite small, the relative average apparent size of individuals in the two groups being about as 10 to 1.

Sample (11). Delaware Kaolin. Same as first report. Colloidal motion more active.

In several of the washed samples, the effect of the removal of some of the coagulative salts or coagulants is shown by the increased colloidal activity.

There will now be given *within brackets*, Mr. Bleininger's very comprehensive descriptions of the several clays, followed by some remarks on the ultramicroscopic evidence.

(1) *English Kaolin*. (This kaolin is of primary origin and comes from St. Austel, Cornwall, England. It is claimed by some geologists that this deposit has been formed from the granites and pegmatites through the action of volcanic gases containing appreciable amounts of fluorine. This kaolin in the crude state is freed from quartz and undecomposed feldspar, by a very elaborate washing process. As a result, this material corresponds quite closely to the theoretical composition, $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. With reference to fineness of grain it seems to have the proper combination of sizes so as to insure the maximum plasticity possible in primary kaolins. Its color is exceptionally white. In the nature of the case all primary clays, not having been transported and acted upon by water, are inherently coarser than all secondary clays which have undergone transportation. The mechanical strength of the dry primary clay is therefore inferior to that of secondary materials. The tensile strength of this clay in the dry state is about 30 pounds per square inch, the compressive strength about 200, and the transverse strength about 70 pounds per square inch. Although lower in truly colloidal clay substance, this clay is still fine enough to serve admirably as a filler for paper and seems to be the best material available for this purpose, especially for the high grades.)

The comparative freedom of this clay from larger size particles shows the care with which the washing and floating took place. The activity of the colloidal motion indicates the absence of coagulating substances, and perhaps the addition of deflocculating substances, or their presence in the local water. It would seem that the relative weakness of the dry clay is due to the uniformity of its particles, but largely also to their hydration, the intensity with which they hold fast to their absorbed water films.

(2) *Georgia Kaolin*. (This material differs geologically from the English kaolin in being of secondary origin, having been transported from its place of origin and consequently having undergone considerable grinding action. While the composition of this clay approaches the kaolinite formula quite closely, still it carries impurities, especially titanates of iron, which impart to the material a creamish color. The plasticity of this clay is

much more developed than with the primary kaolins but it would seem that there is not a sufficient gradation in the size of the particle to develop the best working quality. It must be understood that mere fineness is not the most desirable condition in clay. We must have also a certain gradation of sizes to have the best working qualities. Clays of this type are inclined to be sticky, that is, show excessive plasticity if we may use this term. For this reason also this clay is somewhat inclined to crack during drying, probably due to an excess of colloidal substance. The tensile strength of Georgia kaolin is about 100 pounds per square inch, the compressive strength about 450, and the transverse strength about 250 pounds per square inch.)

This shows a greater proportion of larger particles than (1), due to its inherent nature, to imperfect washing, or to both. The fact that it mixes less readily with water than (1), and shows greater dry strength, indicates that the particles are less highly hydrated and therefore closer together in the "dry" clay.

(3) *Florida Kaolin*. (This material also is of secondary origin and has properties very much akin to those of the Georgia kaolin and differs only in the quality of firing to a whiter color. The tensile strength of the Florida kaolin is about 100 pounds per square inch, the compressive strength about 530, and the transverse strength about 240 pounds per square inch in the dry state.)

Considering the geological history of Florida, this clay has probably been carried a long distance by prehistoric waters, and then thrown out by the precipitating action of the ocean. The gradual raising of the land and subsequent leaching by rain or flood waters would tend to remove pelagic salts, which are evidently easier to wash out than those infiltrated into the Georgia clay after its deposition.

(4) *North Carolina Kaolin*. (This kaolin is of strictly primary origin, being found in contact with the parent rock. It must undergo a very thorough washing process which is rather expensive, owing to the fact that the yield is only about 15 per cent. Although a primary kaolin it differs radically from the English china clay in being much coarser and practically lacking in colloidal material. At least the quantity of this portion is evidently

very low. This is shown by the low strength in the dried state. The tensile strength is not more than 70 pounds per square inch, the compressive strength about 340, and the transverse strength about 150 pounds per square inch. For the reasons stated this kaolin does not replace the English material since it lacks the gradation from the finest to the coarser particles possessed by the latter.)

The relatively large number of coarse particles in this clay, and its consequent deficiency by weight in colloidal material, account for its weakness when dry. To stretch the yield on washing, considerable coarse material has been included. The presence of coagulating salts is indicated by the slow colloidal motion, and by the yellow masses (apparently ferric hydroxide) absorbed by some of the large particles.

(5) *Tennessee Ball Clay No. 5.* (This clay is of secondary origin but has undergone much greater changes than the secondary kaolins like those from Georgia. It has evidently been brought in contact with organic matter from peat or lignite deposits which has entered into the clay structure. Furthermore, the composition has been changed still more by the infiltration of salts of iron giving rise to ferric hydroxide or pyrites. Through this action this clay has become very much more consolidated, stronger and more horn-like in appearance as may be readily observed by whittling a raw lump with a knife. While the primary and secondary kaolins are more or less chalky and earthy, the ball clays cut more with a hard and smooth surface resembling a horn substance. There is, therefore, a great difference between the kaolins and this type of clay. This may be observed at once also by the color which is no longer white or creamish but much darker and sometimes brown or even black. The strength of these clays as is to be expected is much greater than that of the kaolins and in addition this clay substance is able to bind together or bond a considerable amount of inert material, which can not be done by the kaolins. In other words, the ball clays have an excess of plasticity which enables them to do this; and hence they are exceedingly useful in glass refractories and other products in uniting the large quantity of calcined material which must be used. Owing to their dense structure these clays

dry more or less difficultly when used alone in larger masses owing to the exceedingly fine capillary system, which causes the flow of water from the interior to the exterior to be very slow. If, therefore, the evaporation on the surface is at all rapid a strain will be produced owing to the inability of the water to fill up the pore space emptied by evaporation as fast as the latter process takes place. This difficulty, of course, disappears at once when the clay is used to bond together inert matter. The strength of these clays when used alone is apparently not as great as it should be because of the fine fissures and cracks caused during the drying. When admixed with sand the real strength of the clay appears at once. Thus the tensile strength of such a ball clay alone may be 135 pounds per square inch, and when admixed with an equal weight of sand it may still show the same strength. In one case such a ball clay has a tensile strength of 128 pounds per square inch and when admixed with sand equal to its own weight the strength was 158 pounds, showing therefore an actual increase in spite of the admixture with 100 per cent of inert material. The compressive strength of these clays may vary from 600 to 1000 pounds per square inch alone and from 500 to 800 pounds when admixed with sand. The transverse strength of the clay alone usually fluctuates around 500 pounds per square inch.)

The absence of many large particles in this clay indicates its secondary origin, or else washing. The gel groups, slow colloidal motion, and marked crystalloidisis, show the presence of coagulants (iron salts and the diffusible products of their hydrolysis are highly coagulating), against which is probably balanced the protective or deflocculative action of organic extractives. This means great syneresis, which would tend to diminish the dry strength by cracks. However, on admixture with inert or calcined material, especially with an excess of water or on aging the clay may undergo further deflocculation, thus improving its binding strength; for dilution lessens the coagulating action of salts, and so forth, and with aging and agitation, tends to aid hydration and deflocculation.

The wetness of the 50 per cent solution of this clay indicates that the total free surface is small as compared with (1)-(4)-,

that is, the particles average larger; but pugging and blunging should improve its water absorbing properties.

(6) *Kentucky Ball Clay No. 4.* (This clay has also some of the characteristics of the Tennessee ball clay, but it differs somewhat with reference to the structure and plasticity. While the ball clay has usually been in contact with the recent coal and peat formations, clays of the Kentucky type have been subjected to greater pressure in contact with harder lignite deposits. Furthermore, it would seem that the content of iron pyrites is greater in the Kentucky type of clay than in the Tennessee type. The increased pressure has consolidated and indurated the clay much more thoroughly so that it comes from the mine in harder lumps, slaking somewhat more difficultly when brought in contact with water. In other words, this clay represents a transition from the true ball clay to the fire clay type. However, the strength of this clay does not differ appreciably from that of the Tennessee ball clay.)

The many large gel particles, hampered colloidal motion, and very marked crystalloids (with diplococci), are all in line with the history of pressure and high salt or coagulant content. The strong acidity may be due to H_2SO_4 differentially diffused out of ferrous sulphate, which readily undergoes hydrolysis. In consequence of the pressure and other aggregating factors, the clay is less readily miscible with water than (5). But its colloidal particles are small, and the large gel groups evidently have great water-taking capacity; for judging from its stickiness this clay has a somewhat greater total free surface than (5).

(7) *Illinois Kaolin.* (The first unwashed sample was marked Illinois Kaolin Co.—Plastic Clay.) (This clay has been misnamed since it is not a kaolin but a true ball clay, having properties very much like the Tennessee material and in fact is somewhat stronger. It has all the attributes of a ball clay, except that it is considerably lower in organic matter and comes from the mine in clean light colored lumps of considerable hardness. It must be considered a ball clay in every respect, however.)

This is evidently a ball clay which has undergone natural or else artificial washing and purification, for large particles are absent, although there are many small gel groups. The washing

has evidently removed some of the coagulating substances, for though the colloidal motion is hampered, there is no crystalloidis and the clay is not as acid as (6), which it apparently surpasses in free surface.

(8) *Highland Fire Clay*. (This clay represents a type quite distinct from the ball clay in that it has been subjected to greater pressure and occurs in bituminous coal horizons and not with lignite. It is, therefore, consolidated to a considerably greater extent and requires slaking in air to develop its full plasticity. It also contains a considerable amount of iron pyrites which must be removed by washing. This type of clay is quite high in soluble salts, especially sulphates arising from the decomposition of pyrite, which cause the material to react but poorly with the alkaline reagents as regards deflocculation. It is customary to store the clay if possible for a long time so as to wash out the salts as much as possible. The mechanical strength in the dry state of these clays is considerable and at the same time their drying shrinkage is very much less than that of the ball clays. The clay, therefore, is a typical fire clay and has departed from the ball clay type even though its strength and bonding power are equally great. It is a curious fact that in spite of the presence of pyrites these clays do not filter press readily when fresh but do so after weathering for a year. The addition of a considerable amount of acid 0.05 to 0.1 per cent overcomes this deflocculated state and permits of filter pressing.)

The particles of this clay are all relatively large and apparently do not readily disintegrate, for the freshly mixed 50 per cent clay solution shows free water. Pressure, coagulating salts with the absence of organic deflocculators (which diffuse less readily from coal than from lignite), are all factors tending to the dehydration and close union of the clay particles. Since the clay does not take up much water, it should not shrink much in drying.

(9) *LaClede-Christy Bond Clay No. 69B*. (This is a mixture of unknown composition but presumably consisting of Missouri plastic clay such as the Highlands fire clay and Kentucky ball clay.)

The practical absence of large particles in this clay and the smallness and activity of its colloidal particles, indicate careful

washing and treatment to produce deflocculation, to remove flocculating substances, or both. The acidity indicates its precipitation after washing by some acid or acid salt. The clay consists mainly of small but not colloidal particles, and as its 50 per cent solution shows much free water, it should not show much drying shrinkage.

(10) *Plastic Bond Clay, Lester, Arkansas.* (The original sample was marked Plastic Clay, Camden, Arkansas.) (This material is unique in being the American duplicate of the famous Gross Almerode clay formerly imported from Germany for glass house refractories. It differs from most bond clays in being very high in finely divided quartz. The clay usually runs close to 75 per cent in silica. In spite of this siliceous character it possesses excellent plasticity and bonding power. The geological origin of this clay is tertiary but it appears to be a ball clay enriched with silica and underlies a lignite. I might add that this clay is of exceedingly great value and should be exploited commercially much more thoroughly than is being done at the present time.)

The large sharp crystal particles reported are evidently finely divided silica or quartz. The large size and slow motion of the colloidal particles and the marked crystalloidis, agree with Mr. Bleining's suggestion that it is a modified ball clay. The silica would tend to give the clay an interior space lattice, which would facilitate drying and equalize strains, and thus minimize drying shrinkage. The acidity and other factors, indicate much salts or the acid products of their hydrolysis.

(11) *Delaware Kaolin (Newark China Clay Co.).* (This clay is a primary kaolin, being found in contact with the parent rock in Maryland and Delaware. It is usually of a somewhat yellowish color due to its content of ferric oxide. In firing, however, it produces a color very much like that of the Georgia kaolin. Physically this kaolin is not as coarse as the North Carolina nor, of course, is it as fine as the Georgia and Florida secondary kaolins. However, it does not possess the gradation in sizes shown by the English china clay and therefore it can not be said to duplicate the latter. Its strength is somewhat greater than that of the North Carolina kaolin and less than that of the English. Admixed with North Carolina and Georgia kaolin it gives us a very

good porcelain body and in fact we have used it for this purpose very largely. It might be said that we can duplicate the English china clay through a mixture of these three clays very closely, but the unfortunate part from the economic standpoint is that both the North Carolina and Delaware kaolins are not available in large amounts. We are hence lacking in this country in primary kaolins; and in spite of what some say, this deficiency has not been made good up to the present time. No amount of treatment will convert the Georgia kaolin into a primary one of the Cornwall type. If we had in this country a larger supply of North Carolina kaolin the entire difficulty would be solved.)

This differs markedly from the English kaolin (1). It contains more large reticulated gel groups, and though its colloidal particles are small, their motion is hampered and they show marked crystalloidis (with diplococci). Apparently this clay has possibilities unrealized because of entire absence of treatment, or perhaps because of improper treatment. It would seem that this clay, if scientifically handled, might be worked into a good substitute for English kaolin, at least for some purposes.

In conclusion I would remark that these preliminary ultra-microscopic examinations indicate that a thorough study of clays along the lines of colloid-chemical principles and analysis will throw much light upon many obscure phenomena met with by those who use clay for ceramic and other purposes. These factors extend their influence not only to the formative part of the ceramic process, but also to the subsequent drying, baking, and firing or burning; and their effects are traceable up to the zone of actual fusion.

RIDGEFIELD, CONN.

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

THE FUSIBILITY OF MIXTURES OF GRAPHITE ASH AND BOND CLAYS*¹

BY R. N. LONG

It is generally considered that the refractoriness of the bond clay in graphite crucibles is materially reduced by the ash content of the graphite. Graphites for the manufacture of crucibles are graded for the market in terms of graphitic carbon or the percentage of ash which remains after the carbon has been ignited. Specifications² usually require not less than 85 per cent to 90 per cent graphitic carbon or not more than 10 per cent to 15 per cent ash. It is possible to refine the Ceylon variety to almost 100 per cent carbon³ but as commonly prepared for crucible manufacture the best grades of lump seldom assay higher than 90 per cent carbon, while the chip grades, small percentages of which are sometimes used in crucibles, will fall as low as 70 per cent carbon. With the use of modern milling machinery Alabama producers are now marketing number 1 flake and number 2 flake which will compare favorably by chemical analysis⁴ with the two Ceylon grades. Actual foundry tests⁵ indicate that Ceylon graphite can be replaced by the Alabama flake without shortening the life of the crucible, although these tests were not sufficiently extensive to be conclusive. According to the most recent quotations⁶ on graphite, Ceylon lump is now selling at 15 cents per pound and Alabama number 1 flake at 10 cents per pound.

*Read February 23, 1920, at the meeting of the American Ceramic Society in Convention at Philadelphia.

¹ By permission of the Director, U. S. Bureau of Mines.

² H. G. Ferguson, *Min. Res.* 1917; *U. S. G. S.* 1918, p. 97.

³ H. P. H. Brummell, *Trans. Can. Min. Inst.* 22, 1919.

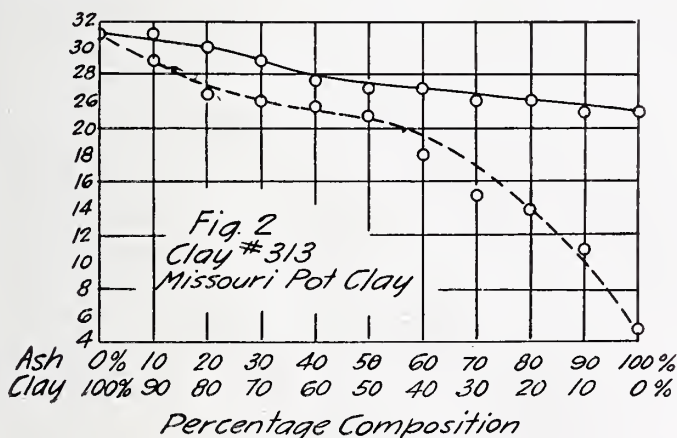
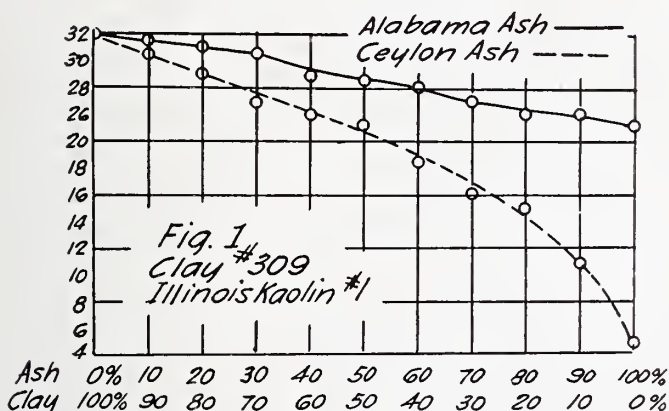
⁴ Geo. B. Dub, "Preparation of Crucible Graphites," War Min. Investigations, p. 21.

⁵ R. T. Stull, "Crucibles Under Brass Foundry Practice," *Jour. Am. Ceram. Soc.*, 1919, p. 224.

⁶ *E. & M. Jour.*, p. 372, 109, No. 5, January 31, 1920.

Tests¹ on 16 Alabama graphites have shown their ashes to be far more refractory than Ceylon ash. In a crucible this ash is

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gradually formed by the burning out of the carbon, and thus be-

¹ M. C. Booze, "Fusibility of Graphite Ash and Its Influence on the Refractoriness of Bond Clays," *Jour. Am. Ceram. Soc.*, 2, 66 (1919).

comes free to exert any contact fluxing action it may possess, on the crucible body. A certain amount of fluxing may be beneficial, since the formation of a glaze on the surface of the crucibles retards further oxidation of the graphite and reduces the production of ash. Thus the life of the crucible is prolonged.

Some crucible users advocate the application of a flux or glaze to the surface of a new crucible to promote the formation of this protective coating. It would seem that the proper control of the ash content might assist in the glaze formation and make possible the use of graphite of a lower carbon content than is now considered permissible. Since there is very little demand for the more impure grades they can be purchased at a lower cost and crucibles produced which might be capable of developing a good glaze without reducing the refractoriness or value of the crucibles themselves, because the graphite must be oxidized before the ash can exert its fluxing action upon the clay.

Previous work on the fusibility of graphite ash¹ indicates that although the ash alone may show a comparatively low fusion point, it is not a very active flux in contact with the bond clay. Ceylon ash alone deformed at cone 2, but when 12 per cent of the ash was introduced into a bond clay, it reduced the refractoriness from cone 30 to cone 26, which is a safe temperature above that generally used in steel melting, and, therefore, far above that used in melting brass.

This investigation, following up the work of Mr. M. C. Booze, was undertaken to determine the effect of increased amounts of ash on the refractoriness of the bond clay, and to determine whether an eutectic existed between the graphite ash and the bond clay. If the 10 per cent to 15 per cent of ash generally present in the graphites used in manufacturing crucibles, does not lower the refractoriness of the bond clay sufficiently to be detrimental at brass and steel melting temperatures, the use of graphites higher in ash might be permissible in crucibles in so far as the refractoriness is concerned.

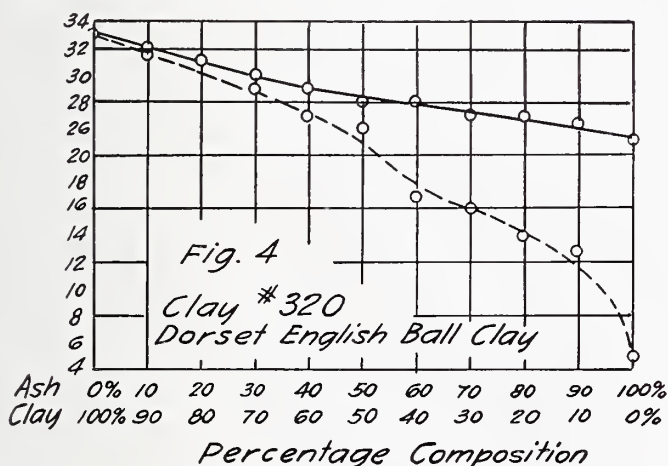
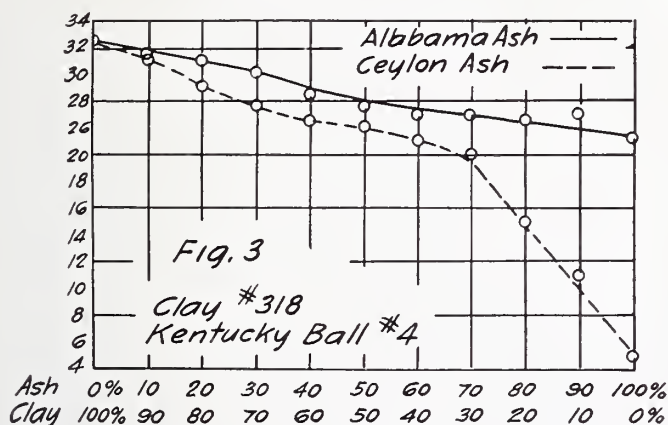
Laboratory Tests

A representative sample of Alabama ash was obtained by blending, in equal parts, six graphites which had been previously

¹ Booze, M. C., *loc. cit.*

sampled by quartering. This mixture, which consisted of three parts number 1 Alabama flake, two parts number 2 flake and one

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part dust, was oxidized in a ventilated muffle kiln at 800 degrees C for several days. A sample of Ceylon crucible graphite was oxidized in the same manner.

From each of these ashes a small sample was forwarded to the Pittsburgh Station of the Bureau of Mines for analysis, the results of which are given in the following table:

| | Ceylon ash Per cent | Alabama ash Per cent |
|--------------------------------------|------------------------|-------------------------|
| SiO ₂ | 55.2 | 56.12 |
| Al ₂ O ₃ | 27.4 | 33.9 |
| Fe ₂ O ₃ | 7.5 | 9.24 |
| CaO..... | 2.1 | nil |
| MgO..... | 1.2 | 0.04 |
| Ignition loss ¹ | 0.4 | 0.13 |
| | <hr/> 93.8 | <hr/> 99.43 |

Standard sized cones were molded from the ash, using dextrine as a binder and the deformation temperatures determined in a gas-fired pot furnace, using compressed air. The flame was distributed by three small gas burners entering at angles nearly tangential. For the clay and ash mixtures, four domestic clays and two imported clays, Klingenberg (number 322) and Dorset English ball clay (number 320) were selected from those giving the best results in brass and steel melting crucibles tested.²

Cones were made of mixtures of Alabama ash and clay, and Ceylon ash and clay in a regular series from 10 per cent ash and 90 per cent clay to 90 per cent ash and 10 per cent clay, each intervening member of the series being 10 per cent richer in ash at the expense of the clay. The deformation temperatures of these mixtures and also of each clay alone are recorded in terms of standard cones, as shown in Table 2.

The sample of Ceylon ash had a comparatively low deformation point—cone 5, while the more refractory Alabama ash softened at cone 23+. The analyses of these ashes indicate that the Alabama ash is very low in alkali and alkali earths whereas these fluxes are comparatively high in the Ceylon ash, which is evidently responsible for its low deformation temperature.

¹ It may be assumed that the alkalies, sodium and potassium oxide, if determined, would bring up the total of the Ceylon ash. The alkali content of the Alabama ash is evidently low.

² R. T. Stull, "Behavior of Bond Clays in Crucibles Under Brass and Steel Melting Practice," *Jour. Am. Ceram. Soc.*, 1920.

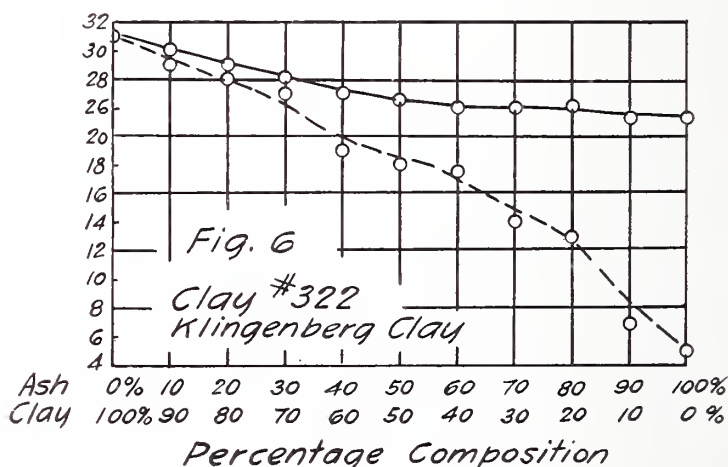
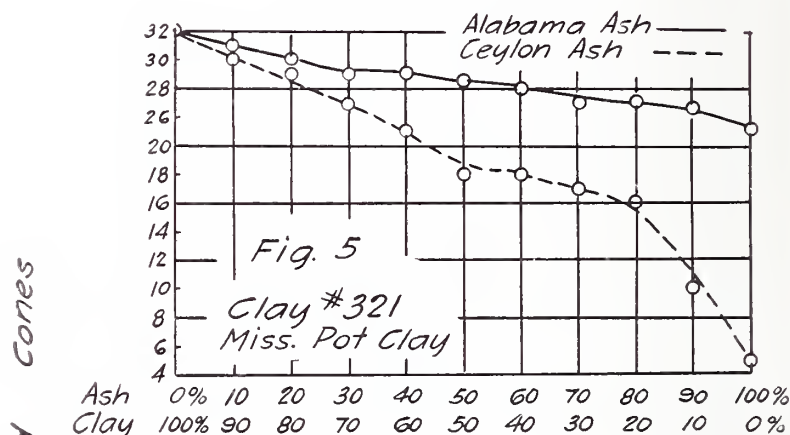
TABLE 2—DEFORMATION POINTS OF MIXTURES OF GRAPHITE ASH AND BOND CLAY IN STANDARD CONES.

| Ash | Clay | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|-----|------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|----------|--------------------------------|--------------------------------|----------|
| | | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent |
| | | 100 | 90 | 80 | 70 | 60 | 50 | 40 | 30 | 20 | 10 | 0 |
| | | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent |
| 309 | Ala. | 32 | 31 ¹ / ₂ | 31 | 30 ¹ / ₂ | 29 | 28 ¹ / ₂ | 28 | 27 | 26 | 26 | 23+ |
| | Cey. | 32 | 30 ¹ / ₂ | 29 | 27 | 26 | 23+ | 18 ¹ / ₂ | 16 | 15 | 11 | 5 |
| 313 | Ala. | 31 | 31 | 30 | 29 | 27 ¹ / ₂ | 27 | 27 | 26 | 26 | 23+ | 23+ |
| | Cey. | 31 | 29 | 26 ¹ / ₂ | 26 | 26— | 23 | 18 | 15 | 14 | 11 | 5 |
| 318 | Ala. | 32 ¹ / ₂ | 31 ¹ / ₂ | 31 | 30 | 28 ¹ / ₂ | 27 ¹ / ₂ | 27 | 27 | 26 ¹ / ₂ | 27 | 23+ |
| | Cey. | 32 ¹ / ₂ | 31 | 29 | 27 ¹ / ₂ | 26 ¹ / ₂ | 26 | 23 | 20 | 15 | 11 | 5 |
| 320 | Ala. | 33 | 32 | 31 | 30 | 29 | 28 | 28 | 27 | 27 | 26 ¹ / ₂ | 23+ |
| | Cey. | 33 | 31 ¹ / ₂ | 31 | 29 | 27 | 26 | 17 | 16 | 14 | 13 | 5 |
| 321 | Ala. | 32 | 31 | 30 | 29 | 29 | 28 ¹ / ₂ | 28 | 27 | 27 | 27 | 23+ |
| | Cey. | 32 | 30 | 29 | 27 | 23 | 18 | 18 | 17 | 16 | 10 | 5 |
| 322 | Ala. | 31 | 30 | 29 | 28 | 27 | 26 ¹ / ₂ | 26 | 26 | 26 | 23+ | 23+ |
| | Cey. | 31 | 29 | 28 | 27 | 19 | 18 | 17 ¹ / ₂ | 14 | 13 | 7 | 5 |

The cones of the clay-ash mixtures, unlike the ash alone, do not deform regularly but instead the tip of the cone generally bends stiffly until it is about halfway down and then hesitates until the temperature is increased 20 to 40 degrees. This is perhaps due to a tendency of these cones to swell, thus increasing their cross-section and stability. In determining the softening points, a time-temperature curve was followed as closely as possible, increasing the temperature at a rate of 10 to 15 degrees a minute, as suggested by the Committee on Standards. The slow rate of deforming of these cones slightly impaired the accuracy of their softening point determinations. The deformation of the clay-ash mixtures, with one exception, conform regularly to a gradually declining curve. With 100 per cent clay at the upper end, as the ash content increases, a slightly lower deformation temperature occurs until 100 per cent ash is reached as indicated, at the lower end of the curve. In the one exception the mixture, containing 90 per cent Alabama ash and 10 per cent number 318 clay, has a deformation of cone 27, which is slightly higher than that of the mixture of 80 per cent ash and 20 per cent clay. A second test checked the result of the first. There are no other irregularities or breaks in the curves and this one is not sufficiently marked to indicate an eutectic. The absence of eutectics might be expected

since the analyses of the ashes show a similarity to certain clay analyses. No clay-ash mixture shows a deformation temperature as low as the ash alone.

DEFORMATION TEMPERATURES GRAPHITE ASH-BOND CLAY MIXTURES



The fluxing action of the Ceylon ash is more marked than that of the Alabama in lowering the refractoriness of the bond clays, especially with the higher percentages of the Ceylon ash. As much as 90 per cent of the Alabama ash may be introduced into bond clays without lowering the fusion point of the mixture below cone 26, to which point it is lower by 30 to 40 per cent of the Ceylon ash. Since the ash in a crucible after the carbon has been burned out is not as intimately associated with the clay as it is in the cones tested, it is evident that the ash would be still less active as a flux in the crucible than the foregoing results indicate.

The behavior of the six clays, throughout the clay-ash mixtures is very similar. As a rule the bond clay with the highest initial refractoriness retains this lead over the less refractory clays in all the percentages of clay-ash mixtures. This would indicate that a larger percentage of ash could be used with a more refractory clay without lowering the fusibility of the mixture below that of a mixture containing a less refractory clay and a smaller percentage of ash.

Conclusions

In accordance with the findings of Mr. Booze, the ash from the Alabama graphite has a higher fusion point than the ash from the Ceylon and is less active as a flux in bond clay-ash mixtures.

No eutectic was found to exist between graphite ash and bond clay.

The action of these graphite ashes as a flux on bond clays indicates that graphite higher in ash than that now employed might be used in crucibles without seriously reducing the refractoriness.

Increased percentage of graphite ash in bond clay-ash mixtures lowers the refractoriness of the mixtures proportionately but does not destroy the initial advantage one clay may have over another in refractoriness.

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NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

AN APPROXIMATE DETERMINATION OF THE MELTING- POINT DIAGRAM OF THE SYSTEM ZIRCONIA-SILICA^{1,2}

BY EDWARD W. WASHBURN AND EARL E. LIBMAN

1. Introduction

In order to form an intelligent opinion of the possibilities of manufacturing refractories containing zirconia as a principal constituent, the phase rule diagrams of the binary and ternary systems composed of zirconia with the other refractory oxides ought to be determined. The present investigation was intended to be the first one of a series dealing with this general problem, but the results obtained indicated that these diagrams probably all lie in the temperature region above 1700°C . The furnace equipment of our laboratory thus proved inadequate for the prosecution of such a study and as our resources were not sufficient to provide the necessary equipment, further investigation in this field has been abandoned. Since, however, there are at present in the literature no data whatever concerning melting point diagrams of systems containing zirconia, our preliminary results on the system zirconia-silica seem worthy of publication, although they leave much to be desired in the way of both accuracy and completeness.

2. Purification of Materials

The silica employed was a pure quartz powder of the quality used in the manufacture of optical glass.

The zirconia was obtained from a sample of zirconium hydroxide obtained from the Foote Mineral Company and having after ignition the following composition:

¹ Received February 27, 1920.

² Based upon the thesis of Earl E. Libman submitted to the Graduate School of the University of Illinois in partial fulfillment of the requirements for the degree of Master of Science, January 1920.

| | Per cent |
|--------------------------------------|----------|
| ZrO ₂ | 99.17 |
| SiO ₂ | 0.05 |
| MnO..... | 0.06 |
| Fe ₂ O ₃ | 0.71 |
| Al ₂ O ₃ | Trace |
| CaO..... | Trace |
| | <hr/> |
| | 99.99 |

In order to remove the 0.7 per cent of iron from the material, it was treated with phosgene gas. To test the efficiency of this method it was first tried out in a sample of baddeleyite having the following composition: ZrO₂, 79.16; SiO₂, 14.87; Fe₂O₃, 2.31; TiO₂, 1.79; and MnO, 1.76 per cent. The material was heated in a tube furnace at 300° C, while a current of COCl₂ was slowly passed through. Every two hours a sample was taken out and analyzed for SiO₂ and Fe₂O₃. The results obtained are given in table 1.

TABLE 1.—ILLUSTRATING THE EFFICIENCY OF THE PHOSGENE PROCESS FOR REMOVING IRON FROM ZIRCONIA

| Sample | No. 1 | No. 2 | No. 3 | No. 4 |
|---------------------------------------|-------|-------|-------|-------|
| Hours in COCl ₂ at 300° C | 2 | 4 | 6 | 8 |
| %SiO ₂ | 14.76 | 13.89 | 13.52 | 11.96 |
| %Fe ₂ O ₃ | 2.00 | 1.03 | 0.02 | Tr. |

Qualitative tests showed fair amounts of both TiO₂ and MnO₂ still left in the material.

The excellent results obtained above warranted the treatment of the specially purified material in the same manner. In this manner the last traces of iron were removed from the zirconia so that portions fused with sodium carbonate, dissolved in hydrochloric acid, and tested with sulphocyanate gave no coloration.

3. Preparation of the Fusion Mixtures

The melting temperatures of pure ZrO₂ and of seven mixtures of ZrO₂ and SiO₂ were investigated. The mixtures were made up in the following molecular proportions: 1 ZrO₂.1 SiO₂; 1 ZrO₂.2 SiO₂; 1 ZrO₂.3 SiO₂; 2 ZrO₂.3 SiO₂; 1 SiO₂.2 ZrO₂; 1 SiO₂.3 ZrO₂; and 2 SiO₂.3 ZrO₂.

The required amounts of ZrO_2 and SiO_2 were carefully weighed and ground together for four hours in an agate mortar. The well mixed powder was then fused in a graphite crucible in a small arc furnace and the extremely hard crystals reduced to a coarse powder in a hardened steel mortar. The mixture was next ground extremely fine in a hardened steel mortar, and the impalpable powder thus obtained was boiled for several hours with dilute HCl under a reflux condenser to remove any particles of iron which might have been introduced from the steel mortar. The powder was then removed from the acid by filtration with suction, using a Büchner funnel, and washed with cold water until the washings gave no coloration with KSCN . This grinding, fusion, regrinding, extracting with dilute HCl , and washing free from iron was repeated *three times* with each mixture.

The final product was in each case a dark gray powder. The color was due to carbon either as such or in the form of carbide, and upon burning at a bright cherry red in a stream of oxygen gas the mixtures came from the furnace a pure snow white.

A portion of each mixture was made into sticks in the following manner. A line of the powder was spilled on a carbon plate and shaped with two spatulas until it had a triangular section. This was then slowly passed under a thirty-ampere A. C. electric arc, which gave a stick fused on the upper side. The stick was then turned over so as to expose the unfused side, and again passed through the arc. The result was a well fused crystalline pencil of the material about two inches long and one-eighth inch in diameter.

4. The Melting Point Apparatus

The melting points of the sticks were determined by feeding them slowly into an oxyacetylene flame and noting with the aid of an optical pyrometer the temperature of the small droplets of fused material which formed at the tip of the stick. This procedure apparently did not produce the eutectic melt as would have resulted from a slower rate of heating, but gave instead a melt having the same composition as the stick, owing to the small region which was subjected to the high temperature. The spherical droplets obtained were not, however, analyzed as the

roughness of the method and of the temperature measurements hardly made it worth while.

A diagram of the apparatus is shown in figure 1. The optical

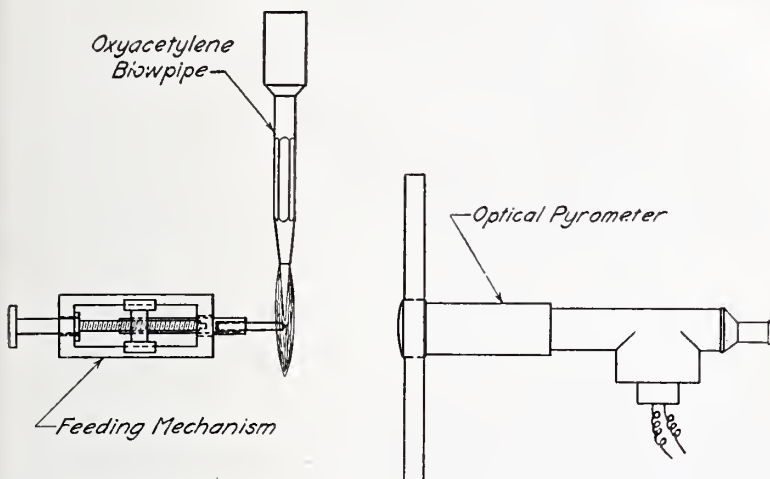


FIG. 1.

pyrometer employed was a Leeds and Northrup instrument of the Holborn-Kurlbaum type calibrated for us by the Bureau of Standards. The temperature readings could be duplicated to about $\pm 100^\circ$.

5. The Melting Point Data

The melting points of the various mixtures secured in this way are shown in table 2 and the corresponding melting point diagram in figure 2.

It will be noticed that the diagram shows the presence of a compound corresponding in composition to the natural mineral zircon and having the same melting point.

A heavy black line is drawn in the figure separating the mixtures on the SiO_2 side from those on the ZrO_2 side. The mixtures on the ZrO_2 side of this compound are obviously composed of ZrO_2 and ZrSiO_4 . These mixtures melted sharply and were very fluid, the drops forming readily and breaking away im-

TABLE 2.—MELTING POINTS IN THE SYSTEM $\text{ZrO}_2\text{--SiO}_2$

| Composition | "Black body" temperature $^{\circ}\text{C}^{\circ}$ |
|---|---|
| ZrO_2 | 2470 |
| $\left. \begin{array}{l} 3 \text{ ZrO}_2 \\ 1 \text{ SiO}_2 \end{array} \right\}$ | 2435 |
| $\left. \begin{array}{l} 2 \text{ ZrO}_2 \\ 1 \text{ SiO}_2 \end{array} \right\}$ | 2400 |
| $\left. \begin{array}{l} 3 \text{ ZrO}_2 \\ 2 \text{ SiO}_2 \end{array} \right\}$ | 2210 |
| $\left. \begin{array}{l} 1 \text{ ZrO}_2 \\ 1 \text{ SiO}_2 \end{array} \right\}$ | 2300 |
| Natural Zircon* | 2300 |
| $\left. \begin{array}{l} 2 \text{ ZrO}_2 \\ 3 \text{ SiO}_2 \end{array} \right\}$ | 2170 |
| $\left. \begin{array}{l} 1 \text{ ZrO}_2 \\ 2 \text{ SiO}_2 \end{array} \right\}$ | 2170 |
| $\left. \begin{array}{l} 1 \text{ ZrO}_2 \\ 3 \text{ SiO}_2 \end{array} \right\}$ | 2170 |

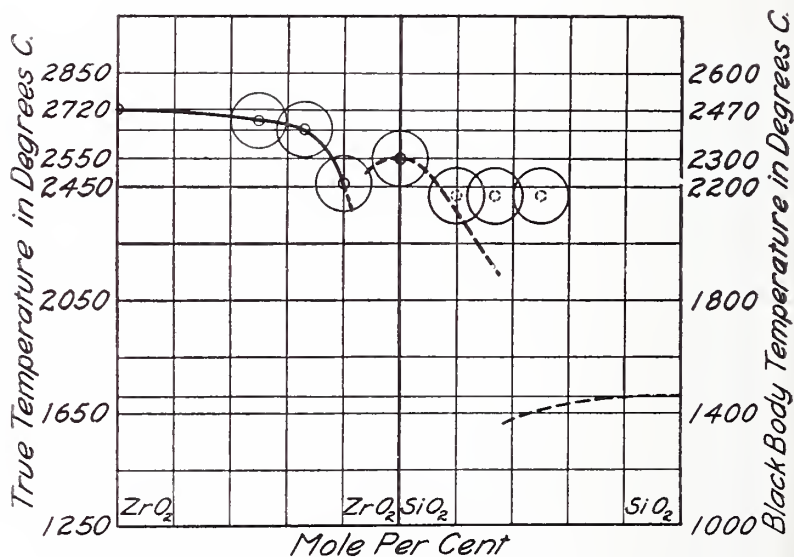


FIG. 2.

*The sample of mineral used in this determination was light yellow in color, but burned to a pure white in the flame.

mediately. On examination after cooling, they were found to be perfect spheres, showing complete liquefaction.

The mixtures on the SiO_2 side are obviously composed of SiO_2 and ZrSiO_4 . These fused with difficulty, the fused material did not fall off but hung down from the main stick in threads, and examination after cooling did not reveal the spherical form noticeable with the mixtures on the ZrO_2 side. It is evident that the method employed is applicable only to mixtures that do not possess too high a viscosity. For this reason no reliance can be placed on the data obtained here for mixtures containing excess of SiO_2 . The true melting points must evidently lie lower than those recorded.

6. True Temperatures

The temperatures given in table 2 and indicated on the right hand side of the diagram in figure 2 are "black body temperatures" that is, they represent the temperatures to which a "black body" would have to be heated in order to give the same pyrometer readings as those actually obtained. The true temperatures are probably considerably higher than those indicated by the pyrometer.

In order to estimate the magnitude of the correction which should be applied in order to convert the observed readings into true temperatures, the melting points of CaO and of MgO were determined with the same apparatus, with the following results:

CaO obs. m. p. 2370° , true m. p. 2570° , corr. 200°

MgO obs. m. p. 2470° , true m. p. 2800° , corr. 330°

By assuming a correction (250°) of the same order of magnitude for the mixtures used in this investigation, the "true temperatures" shown on the left-hand side of the diagram in figure 2 were obtained. They are perhaps correct within the accuracy of the data themselves.

7. Conclusions

From the diagram shown in figure 2 the following conclusions may be drawn:

(1) For use as a refractory up to about 2550° the presence of silica as an "impurity" in zirconia is not necessarily detri-

mental since the fluxing action of this impurity can be eliminated by adding enough more silica to bring its total content up to 33 per cent.

While such a refractory will be nearly as resistant to high temperatures as the pure zirconia itself, its other physical and chemical properties will, of course, be those of zirconium silicate which for some purposes might make it a less desirable refractory than the oxide. So little is known concerning the properties of the silicate, however, that further comparison of the two materials is not possible at present.

(2) The diagram also suggests that refractories of considerable strength might possibly be manufactured from powdered zircon bonded with a small quantity of a mixture of zirconium hydroxide and precipitated silica in molecular proportions and fired in an electric furnace.

Summary

1. The melting point of pure ZrO_2 is about 2700°C .
2. The melting point of the natural mineral zircon is about 2550°C . A mixture of ZrO_2 and SiO_2 in molecular proportions melts at the same temperature as the natural mineral.
3. A eutectic between ZrO_2 and ZrSiO_4 occurs in the neighborhood of 2300°C .
4. Iron may be completely removed from zirconia by heating it to 300° in a current of phosgene.

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NOTICE—Further discussion of this subject is solicited. All communications should be sent to the Editor.

THE EFFECT OF THE SIZE OF GROG GRAIN IN A TERRA COTTA BODY*

By H. E. DAVIS

In beginning a study of this kind, it was found profitable to refer to what work had already been done along this, or similar lines. Below is given a brief combined summary of the following references: "Notes on Action of Grog in Ceramic Bodies," by S. Giesjbeck, *Trans. Am. Ceram. Soc.*, Vol. 17. "Effect of Grog in a Fire Clay Body," by Fulton and Montgomery, *Trans. Am. Ceram. Soc.*, Vol. 17, and "Effect of Size of Grog in a Fire Clay Body," by F. A. Kirkpatrick, *Trans. Am. Ceram. Soc.*, Vol. 19.

Grog may be defined as burnt clay, or its burnt products in the ground state, coarse or fine, according to the use to which it is put. The principal functions of grog in a clay body are: (1) To counteract both drying and burning shrinkage. (2) To decrease plasticity. (3) To insure safer drying and burning.

Previous studies, in general, working in all cases with refractory fire-clays, have reached the following conclusions: (1) With increasing grog amount, water of plasticity, shrinkage, dry and burned strengths decrease. (2) With increasing grog amount, porosity and absorption increase.

Kirkpatrick in his study (*Trans. Am. Ceram. Soc.*, Vol. 19), keeping the amount constant, and varying the size, found practically the same results with increasing sizes as others found with increasing amount.

In studying the effect of grog, which plays so important a part in all the cruder clay wares, there may be five variables—amount of grog, kind of grog, shape of grain, size of grog particle, and relative proportion of sizes. In this study the size of particle has been the only one considered, all others remaining constant.

The object of this study has been to determine the effects of various separate sizes of grog particle upon a terra cotta body with

*Received February 27, 1920.

regards to raw and burned strength, dry and total linear shrinkage, water of plasticity, absorption of the burned body, smoothness of texture, and adaptability to taking a slip coating.

Body Materials.—The material used for grog was broken saggars from an electrical porcelain plant, having been repeatedly fired to cone 12. The grog was ground in a dry pan and screened into various sizes with standard screens. The sizes of grog selected were: 10-16-mesh, 16-20-mesh, 20-30-mesh, 30-35-mesh, 35-48-mesh, 48-65-mesh, 65-100-mesh, and 100-dust. The clays used were Dogtown, N. J. sagger clay, a very soft red clay, burning to buff under good oxidizing conditions, and Zanesville stoneware clay, an extremely hard gray colored clay burning to a good buff. The clays were broken up in a set of rolls until the maximum size would probably pass a 6-mesh screen.

Body Mixtures.—The bodies for the trials were made containing 40 per cent grog, 40 per cent Zanesville stoneware clay, and 20 per cent Dogtown sagger clay. This made eight bodies, and for purposes of comparison with conditions which probably would obtain in factory practice, a ninth body was made of the same proportions, the grog ingredient, however, containing all material passing a 10-mesh screen. For purposes of further comparison, a few bars were made from each of the individual clays, containing no grog, and also a mixture of the two clays in the proportions used throughout. All bodies containing grog were first mixed with water by hand and worked a while in this manner. They were then run several times through a set of rolls, set sufficiently far apart so as to effect no crushing action upon the grog particles. After considerable hand wedging, the samples were hand pressed in a brass mold into bars $1 \times 1\frac{1}{8} \times 8$ inches. Also flat pieces about $1 \times 2\frac{1}{2} \times 5$ inches were pressed in plaster molds and finished. The bars were used for shrinkage measurements, breaking strength and absorption; the flat pieces for surface texture and slip coating. A separate ball was made for determining the water of plasticity.

Drying and Burning.—Eighteen bars were made from each body, except the 100 per cent clay bodies, of which only seven

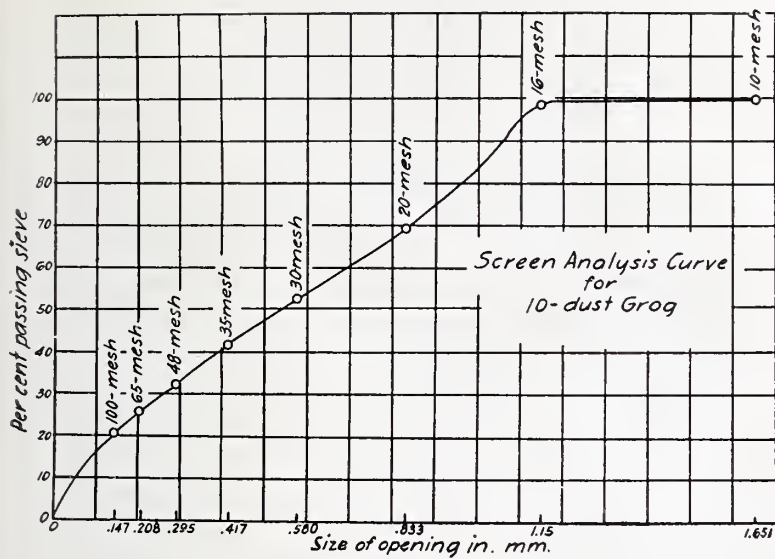


FIG. 1.

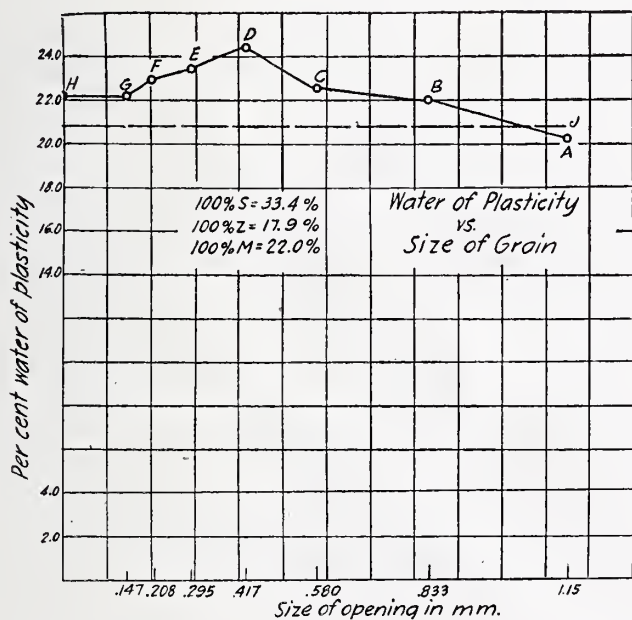


FIG. 2.

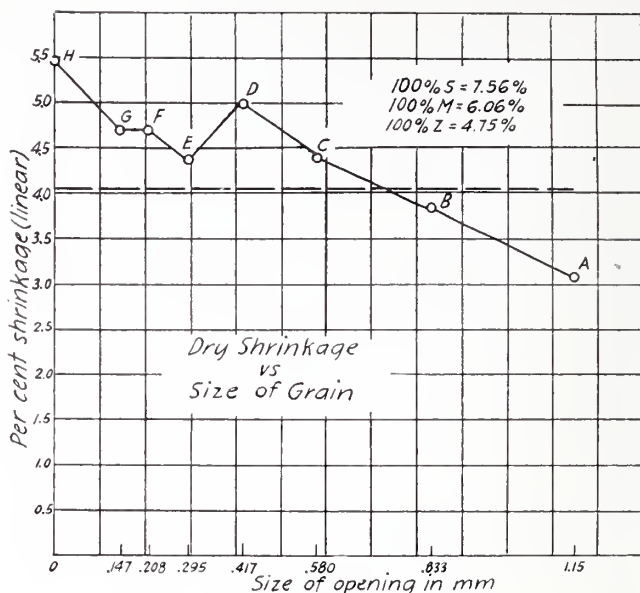


FIG. 3.

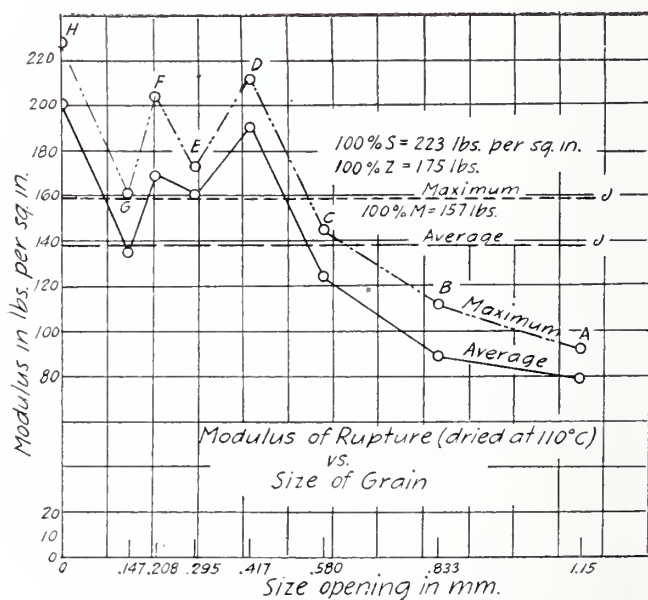


FIG. 4

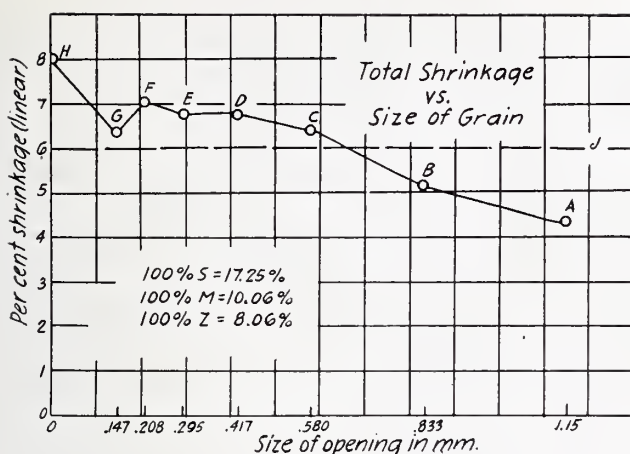


FIG. 5.

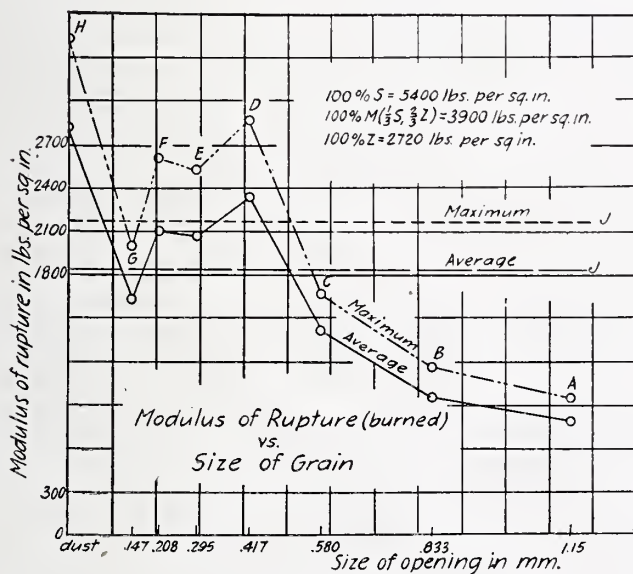


FIG. 6.

bars each were made. Eight bars were taken from each set, air dried to constant weight, and then dried at 110°C to constant weight, while the remainder of the bars were burned. Four of the flat pieces were made and all were sprayed with a standard vitreous slip of the following composition: Flint 20, Cornwall stone 45, English ball clay 10, and English china clay 25 per cent.

The bars were placed in saggers, each sagger containing bars from every series, and a plaque of cone tips. These saggers, and those containing the slip coated trials, were burned in a small gas-fired test kiln. Unfortunately the burn resulted in a range of

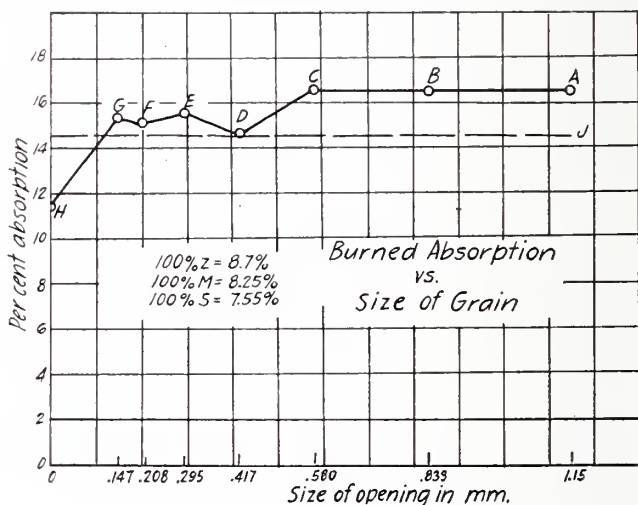


FIG. 7.

practically four cones, the lowest being a little below cone 2, and the highest a little above cone 5. The temperatures in the four saggers used were as follows: Cone 1-2, cone 2 good, cone 3, and cone 5-6. Since each sagger contained bars from every series, discrepancies in results, due to this temperature difference, were offset and the results are comparable, as all averages are based on figures extending throughout the range. Accurate account was kept, however, of the temperature to which each bar was burned, and, as might be expected, a gradual increase in strength and decrease of absorption was noticed with increasing vitrification, but no appreciable difference in shrinkage.

Methods of Testing.—Dry Trials. The eight bars from each series, having been dried at 110 degrees C, were measured for linear shrinkage, and broken on a standard Riehle briquette breaking machine, equipped with a transverse breaking attachment designed at the U. S. Bureau of Mines. Bars were broken on a 5-inch span and the halves on a 3-inch span. The water of plasticity balls were also dried at 110 degrees C and reweighed to determine the loss. No bars were counted into the average in either dried or burned calculations, whose strength figured below 70 per cent of the maximum.

Burned Trials. The burned bars were measured for shrinkage in the same manner, and broken in the same machine on 5-inch and 3-inch spans, after adjusting the machine to accommodate the much greater load. Three pieces of broken bar, one from low, high and medium fire, were selected from each series for absorption trials. These were weighed and put into a pan of water. They soaked in cold water over forty hours and were then boiled for about two hours, and reweighed.

Methods of Calculation.—(1) Per cent linear shrinkage was figured on the basis of the plastic or original length.

(2) Per cent water of plasticity or tempering water =

$$\frac{\text{Plastic weight} - \text{dry weight}}{\text{dry weight}} \times 100$$

(3) Modulus of rupture or transverse strength in pounds per square inch = $\frac{3 P L}{2 b d^2}$, where P = load in pounds, L = span in inches, b = breadth of bar and d = depth.

(4) Per cent absorption = $\frac{W - D}{D} \times 100$, where W = wet weight and D = dry weight.

In order to make the reading of blue prints and tables easier, the bodies have been lettered according to the following system:

S = 100 per cent Dogtown sagger clay body.

Z = 100 per cent Zanesville stoneware body.

M = $66\frac{2}{3}$ per cent of Z and $33\frac{1}{3}$ per cent of S.

Body mixtures are as follows:

| Body | Grog Per cent | Dogtown Sagger clay Per cent | Zanesville clay Per cent |
|------|------------------|------------------------------------|--------------------------------|
| A | 40 10-16 mesh | 20 | 40 |
| B | 40 16-20 mesh | 20 | 40 |
| C | 40 20-30 mesh | 20 | 40 |
| D | 40 30-35 mesh | 20 | 40 |
| E | 40 35-48 mesh | 20 | 40 |
| F | 40 48-65 mesh | 20 | 40 |
| G | 40 65-100 mesh | 20 | 40 |
| H | 40 100-dust | 20 | 40 |
| J | 40 10-dust | 20 | 40 |

SCREEN ANALYSIS OF J-GROG¹

(Per cents are per cents retained)

| | | | |
|--------------|-------|----------------|-------|
| 16 mesh..... | 0.60 | 48 mesh..... | 9.50 |
| 20 mesh..... | 30.40 | 65 mesh..... | 6.30 |
| 30 mesh..... | 17.10 | 100 mesh..... | 5.40 |
| 35 mesh..... | 10.50 | —100 mesh..... | 20.20 |

Tables.—Tables 1 and 2 give the average figures in the various properties of the bodies based over the entire range of temperature, while tables 3 and 4 show the variation of strength and absorption due to increased vitrification.

TABLE 1—DRY TRIALS

| Body | Per cent water of plasticity | Per cent dry linear shrinkage | Average modu- lus of rupture lbs. per sq. in. | Maximum modu- lus of rupture lbs. per sq. in. |
|--|------------------------------------|-------------------------------------|---|---|
| 100% S | 33.4 | 7.56 | 223 | 250 |
| 100% Z | 17.9 | 4.75 | 175 | 200 |
| 33 ¹ / ₃ % S } 66 ² / ₃ % Z } | 22.0 | 6.06 | 157 | 188 |
| A | 20.37 | 3.1 | 79.2 | 92.5 |
| B | 22.03 | 3.85 | 89.2 | 112 |
| C | 22.60 | 4.4 | 124 | 145 |
| D | 24.45 | 5.0 | 190 | 212 |
| E | 23.46 | 4.36 | 160 | 173 |
| F | 23.00 | 4.7 | 169 | 204 |
| G | 22.20 | 4.7 | 135 | 161 |
| H | 22.20 | 5.45 | 202 | 228 |
| J | 20.8 | 4.06 | 138 | 159 |

¹ The base line of all curves, marked size of opening in millimeters, refers to the size of opening upon which the grog was retained and not the last size through which it passed. The sizes are taken from the Tyler Standard Screen Scale with the exception of the size 1.15 (16-mesh) and the size 0.580 (30-mesh).

TABLE 2—BURNED TRIALS

| Body | Per cent total linear shrinkage | Average modulus of rupture lbs. per sq. in. | Maximum modulus of rupture lbs. per sq. in. | Per cent absorption |
|--|---------------------------------|---|---|---------------------|
| 100% S | 17.25 | 4745 | 5400 | 7.55 |
| 100% Z | 8.06 | 2530 | 2720 | 8.7 |
| 33 ¹ / ₃ % S } 66 ² / ₃ % Z } | 10.06 | 3410 | 3900 | 8.25 |
| A | 4.36 | 804 | 960 | 16.51 |
| B | 5.14 | 960 | 1190 | 16.47 |
| C | 6.4 | 1420 | 1670 | 16.53 |
| D | 6.75 | 2330 | 2870 | 14.60 |
| E | 6.72 | 2070 | 2520 | 15.5 |
| F | 7.045 | 2100 | 2610 | 15.1 |
| G | 6.375 | 1635 | 2020 | 15.32 |
| H | 7.95 | 2815 | 3430 | 11.40 |
| J | 6.0 | 1836 | 2170 | 14.50 |

TABLE 3—STRENGTH AGAINST TEMPERATURE

| Body | Strength at cone 2— | Strength at cone 2 | Strength at cone 3 | Strength at cone 5+ |
|------|---------------------|--------------------|--------------------|---------------------|
| A | 705 | 764 | 826 | 805 |
| B | 910 | 964 | 1000 | 1127 |
| C | 1346 | 1441 | 1387 | 1537 |
| D | 2253 | 2031 | 2338 | 2475 |
| E | 1886 | 1956 | 2011 | 2210 |
| F | 1939 | 1916 | 2157 | 2268 |
| G | 1552 | 1485 | 1535 | 1721 |
| H | 2551 | 2478 | 2770 | 2787 |
| J | 1706 | 1752 | 1762 | 1817 |

TABLE 4—ABSORPTION AGAINST TEMPERATURE

| Body | Per cent absorption cone 2— | Per cent absorption cone 3 | Per cent absorption cone 5+ |
|------|-----------------------------|----------------------------|-----------------------------|
| A | 17.00 | 16.95 | 15.6 |
| B | 16.70 | 16.70 | 16.0 |
| C | 17.00 | 16.60 | 16.0 |
| D | 14.9 | 14.5 | 14.3 |
| E | 15.9 | 15.4 | 15.2 |
| F | 15.1 | 15.60 | 14.6 |
| G | 15.45 | 15.50 | 15.0 |
| H | 11.60 | 12.00 | 10.60 |
| J | 14.7 | 14.6 | 14.2 |

Summary of Data

1. **Tempering Water versus Size of Grain.**—Results show increasing water of plasticity with finer grog, up to a maximum at

D (30-35 mesh), and decreasing water of plasticity from this point to H (100-dust).

The J (10-dust) body required less tempering water than all others with the exception of the coarsest grog body.

The range throughout the series is 4.07 per cent, and the average for the group is about 22.35 per cent.

2. Dry Linear Shrinkage.—In general, shrinkage increases with fineness of grog grains throughout. There were two exceptions to this conclusion, which should be checked before a definite statement can be made. The D body was abnormally high, and the E body slightly low.

The range is 2.35 per cent and the average shrinkage is 4.43 per cent.

3. Dry Transverse Strength.—In general, results show an increase in strength with finer grain. There are two exceptions here also; D body, which is abnormally high, and G body, which is abnormally low. The strength of the 10-dust body is about an average of the entire series.

The presence of coarse grog lowers very materially the strength of the mixture of clays alone, or the single clays.

4. Total Linear Shrinkage.—The results show a very even tendency toward increased shrinkage with finer grains, duplicating the dry linear shrinkage curve. There was but one exception here, the G body, which ran low. The position of the 10-dust body in dry shrinkage is duplicated in total shrinkage. The presence of 40 per cent grog cut down the shrinkage of the clay mixture alone by from 30 to nearly 50 per cent, depending upon the size of grog.

5. Burned Transverse Strength.—The relative strengths of bodies in the dried state remains unchanged after burning. The relative position of the 10-dust body also remains practically constant. There is a considerable lowering in strength from the mixture of clays alone, down to even the strongest of grog mixtures.

The range in strengths is from 804 to 2815, and the average is 1767 pounds per square inch. The 10-dust body lies slightly above this average.

6. Burned Absorption.—The results show a general tendency toward decreased absorption with finer grain after passing the 20–30 mesh body. There are two slight exceptions in this curve. The D body, and the F body, both of which fall slightly low. Absorption ranges from 11.40 to 16.53 per cent, or 5.13 per cent difference. The absorption of the raw clay mixture is greatly increased by the addition of 40 per cent grog. The average absorption is 15.10 per cent or an increase of 83 per cent over that of the raw clay mixture.

Study of Slip-Coated Trials.—The bodies showing fine cracks and crow-footing were those containing the coarse grog, 10–16 mesh, 16–20 mesh, 20–30 mesh, and the 10-dust body, which may be seen from the screen analysis to be a fairly coarse grog. All other bodies were of smooth, unbroken surface. As the bodies showing cracks are also the weaker bodies, we may safely conclude that strength and compactness, or freedom from cracks go hand in hand. Where strength can not readily be determined, this seems, from the above conclusion, like a very good indicator of comparative strengths of bodies. As an example, the 10-dust body and the 30–35 mesh body may be compared. The 30–35 mesh body showed no cracks and has a very high strength while the 10-dust body showed considerable cracking and was weaker in the breaking test. Although the fine cracks may be noticed in the uncovered body, the slip coating greatly emphasizes their presence.

General Conclusions

In drawing some general conclusions from the results of this research, it seems that to develop good strength, both burned and dry, the grog ingredient should contain a rather large amount of fine material as the coarser material cracks and thus weakens the body. Fine grog is also very desirable in a slip covered body, as by this means a close-fitting smooth surfaced vitreous coating may be obtained, which will stand up well under the strain of weathering. Further study is necessary, however, to determine the best means of proportioning fine and coarse material in the grog ingredient.

Discussion

MR. R. L. CLARE: This paper should be of great advantage to all Terra Cotta Manufacturers in tracing the source of some of their difficulties, such as variation in shrinkage or cracking.

They should realize from reading the results of this investigation, the wide variations in the properties of the body that can occur from a change in the grog size only. If this one property of the grog could be properly controlled, a great improvement would be noted in the uniformity of the material produced.

NOTICE—Further discussion of this subject is solicited. All communications should be sent to the Editor.

THE ART OF POT MAKING¹

BY CHAS. O. GRAFTON

The different methods and operations necessary in the manufacture of a glass melting pot are so numerous that it is impossible to go into detail regarding them all, and this article will only touch on the important items.

The most important factor in the manufacture of a clay pot is the proper selection of the clays of which the pot is to be made. Prior to the beginning of the war in 1914, and as far back as the writer can remember, we were all laboring under the false impression that good clay pots could not be made except when German clay was used. When the war started the importations of German clay were suddenly cut off, and pot manufacturers were compelled to substitute American clay for the German. The big mistake was made of attempting to substitute one single American clay for the German. To date, it has not been the writer's good fortune to discover a single American clay that is a perfect substitute for the German clay, but by blending three American clays, not only is a satisfactory substitute obtained, but in many cases a clay superior to the German clay is produced.

Mixing.—With the clay is added a proportion of calcined clay and pot shell from the old pots, from which the glass and vitrified parts have been carefully removed. As a large proportion of the old pot shell is used, the cleaner it is kept the better; and the glass manufacturers will aid materially in improving the quality of pots by keeping the pot shell as clean and as free from dirt as possible by providing suitable storage for the shell.

The batch, consisting of proper proportions of clay and shell, is thoroughly mixed, slowly run into a mixer and water is added. After it leaves the mixer it drops into a pug mill and is again thoroughly mixed and worked and packed firmly together.

Ageing Pits.—The batch is then carried to the ageing pits, where it is stored away to age for a period of twelve weeks. After

¹ Received February 27, 1920.

many years of experimenting with different periods of ageing, the writer has found that the advantage gained by ageing clay longer than twelve weeks is so little that it does not pay to carry the ageing to a greater length of time. The clay in the ageing pit is carefully covered with canvas, over which are placed heavy sacks and these are kept continually dampened throughout the period of ageing. (See figure 1.)



FIG. 1.—Ageing pits.

After the clay has reached its proper age, it is taken from the ageing pits and run through pug mills or wet-pans and is then given the final work of preparation—that of tramping it with the feet.

Tramping Clay.—The advantage gained from tramping clay is that the clay trampler's feet become as sensitive to the feel of the clay as the pot maker's hands, and the clay trampler becomes as proficient in the work of getting the clay to the proper consistency as the potter would in wadding his clay for the potter's wheel. (See figure 2).

Starting a Bottom.—The first operation in the actual work in the making of the pot is the laying of the bottom. The bottom

of an average pot when dry is four and one-half inches thick. It is formed in four layers, each layer being about one and one-fourth inches thick. The first layer is laid lengthwise of the board, and the next layer crosses it at right angles, and then the next layer lengthwise and the next again crosses it at right angles. The method of laying by hand consists of taking a piece of clay



FIG. 2.—Tramping clay.

approximately 12 by 3 inches in diameter in the hands and throwing the weight of the body on the clay so it will spread out to the proper thickness. It requires about thirty of these rolls for each layer of the bottom. After the bottom is laid it is beaten off to the proper thickness and cut off to a pattern corresponding to the shape of the pot.

Turning Bottoms.—The bottom is then turned over as shown in figure 3, and placed on the board on which the pot is to be built. The board is usually made of heavy timbers with two layers of 2 × 12-inch boards on top of the timbers, and faced with plaster of Paris. On top of the plaster of Paris a small portion of coarsely ground shell is thrown, which enables the pot to shrink or crawl in when drying: An average sized pot, say

44 inches wide by 58 inches long, will shrink one and one-half inches in width and two inches in length. Inasmuch as the bottom of the pot is not exposed to the air, it is necessary to use some other means to dry it. Steam lines run under the bottom boards are very effective; electric lights while being rather expensive, are often used. The most effective method found by



FIG. 3.—Turning the bottom of a glass pot.

the writer has been the placing of a common burlap sack sewed up in a muslin envelope over the bottom of the pot. These sacks are changed several times a day and after being taken from the pots are placed in a dry room or over radiators to dry before being used again.

Working Hand Courses.—After the pot has been cut off and the bevel edge is turned up, the pot maker is ready to put on what is known as the “filling in” spell. This working is usually 12 inches in height and is worked with seven hand courses and five finger courses. The hand courses consist of working the clay on the pot with the ball of the hand with a downward motion. The pot maker is first supplied with rolls which are round pieces of clay about $2\frac{1}{2}$ inches in diameter by 4 inches long. This is

worked against the bevel side that has been turned up, and the side of the pot is held in shape by the left hand, the right hand working the clay, the object being to spread the clay in about one-fourth inches in thickness. (See figure 4.)



FIG. 4.—Working hand courses.

In putting on the hand courses, first one is put on the inside and the next on the outside; the next on the inside and so on until the seven hand courses are all on, after which the pot is beaten up, the working being wedge shape at this point.

Working Finger Courses.—The finger courses are next put on. This is the most difficult part of pot-making, and the pot maker who can not master the art of properly working the finger courses will never become an efficient pot maker. The working of the finger courses is just the reverse of the hand courses, which is a downward motion, while the working of the finger courses is an upward motion, and when the top of the stroke is reached with the right hand, the thumb on the left hand reaches over and breaks down the clay. (See figure 5.) The finger courses alternate, first on the inside and then on the outside, the same as in putting on the hand course.

After the pot has been filled in to a height of 12 inches, it is allowed to stand for several days until the clay has stiffened sufficiently to hold the second working, which consists of working about six inches of clay on top of the first spell with hand courses and finger courses the same as in filling in the pot. It is then allowed to stand for three or four days until the clay stiffens sufficiently to hold the next working.



FIG. 5.—Working finger courses.

Four workings of six inches each in addition to the filling in working, which is twelve inches high, are put on the pot at intervals of several days, allowing the pot sufficient time between each working to stiffen, which brings it to the proper height for turning the shoulder.

Shoulder Working.—The shoulder working is put on in the same manner, except in finishing it is turned in to take the form the crown is to be and allowed to stiffen for about a week to enable the sides to dry out sufficiently to support the heavy weight of the crown. (See figure 6.)

Beating Down Crown.—Various methods are used to crown in the pot. Some pot makers require two or three workings,

but the method followed by the writer is to use a little stiffer clay than has been used on the side of the pots, and to finish the crown in one working, by building the pot up to a foot or so higher than the pot will finish and then using a glass beater to beat it down



FIG. 6.—Shoulder working.

to the proper shape. No forms are used, as the air becoming compressed inside the pot will carry the weight of the crown. It looks easy, but requires considerable skill to properly beat down a crown without caving in the entire pot. (See figure 7.)

Finishing.—After the pot has been finished, the hood is put on, and the pot mouth is cut out. The inside of the crown must then be trimmed off to the proper thickness and carefully smoothed. The usual method employed is to trim the clay off with trimming irons fastened to the end of sticks about the length of broom handles. The writer employs a boy of small stature, one who can slip through the opening in the pot mouth, and once he is inside the work of trimming and smoothing the crown can be quickly and accurately done. The hood is then carefully smoothed down, and the pot allowed to remain on the board several weeks, when it is thrown off and allowed to rest on the front part of the

bottom and on the hood; this enables the bottom to dry. After the bottom has dried sufficiently, the pot is stored in a warm room to become thoroughly dry before it is shipped.

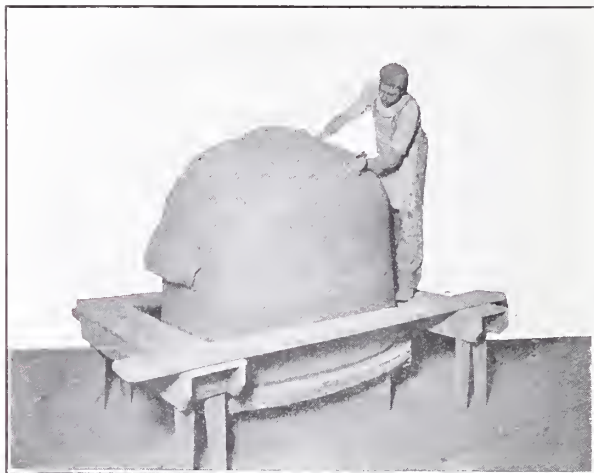


FIG. 7.—Beating down crown.

Pot After Fifty-one Weeks' Use.—Figure 8 shows a cross section of a pot after it had been in continuous operation for fifty-one weeks. If the condition of this pot was anything but what it is, one might say that it would be wrong for the wearing of the pot has been uniform as the thickness of the sides will show, and the interior does not show a pitted condition, but has worn down from the crown to the bottom.

Pot Used for Opal.—Figure 9 shows that I might term the ideal condition in which a pot should leave the furnace. The original thickness of the sides of this pot was four and one-half inches, and there were seven melts of flint glass and forty-three melts of opal made in this pot. It was worn so thin that it was impossible to take it from the furnace whole, and it broke into pieces. The sides of the pot and the bottom had worn to such an extent that in no place were they over two inches thick, and you will note that the pot was very smooth on the inside and free from

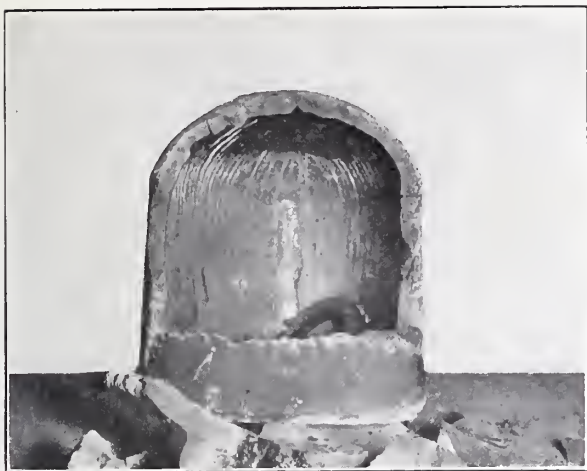


FIG. 8.—Pot after fifty-one weeks use.



FIG. 9.—Pot used for opal glass.

holes. This pot was made from German clays. A later report from the same glass company, using the same opal batch and operating under the same conditions, gave a record of a pot made from all American clay of ninety-nine fillings of opal glass.

GILL CLAY POT CO.
MUNCIE, IND.

Discussion

MR. C. W. BERRY: Mr. Grafton's paper is a valued contribution to the subject of glass pot manufacture. It is especially interesting to learn that successful results have been secured with American clays, thus verifying the statements of other pot manufacturers and laboratories.

The question of ageing clays is one of considerable interest and tests have shown that even twelve weeks ageing is not necessary in order to obtain satisfactory results.

MR. C. W. CRUIKSHANK: In the European plate glass factories the open pots are built up in wooden molds. The mold is placed on a bottom board and the workman throws in lumps of prepared clay until there is sufficient quantity to make the bottom and part of the sides of the pot. The pot maker then handles the clay on the bottom, forcing it gradually up the sides of the wooden mold, pounding and driving out the air and making the bottom homogenous. There are two men to work alternately as the work is very hard. They keep pounding at the clay until it is brought about one-half way up the wooden mold, after which they throw in more clay against the sides with force and pound this into place. By this method a pot is finished in a day instead of building six pots up at the same time and finishing them up at the end of the week.

The pots are placed to dry in small rooms which hold about twenty pots, which are kept at a temperature of about 75° for two or three weeks, then the temperature is increased to 90° or 95°. The floors are heated by means of flues running under them which pass backwards and forwards under the floor. The heat is generated in a combustion furnace and after passing through the flues goes to the stack. Pots, if possible, are kept about nine months before being used.

NOTICE—Further discussion of this subject is solicited. All communications should be sent to the Editor.

A GLAZE STUDY INVOLVING SOME INTERESTING COLORS PRODUCED BY NICKEL OXIDE¹

BY J. D. WHITMER

The behavior of the different coloring oxides in various ceramic mixtures is always interesting and surprising results are frequently noted. Oxide of nickel is no exception in this respect. This study is the outcome of one of those accidental results which frequently come to the attention of the ceramist, and which make his work so fascinating.

In the transactions of our Society we find two references on the color effects produced by nickel oxide. In volume VI, page 195, Geijsbeck, in a discussion, states that the following colors had been obtained from oxide of nickel: Violet, blue, green, yellow, red and brown. In volume XIV, in an article entitled "Colors Produced by Nickel Oxide in Ceramic Mixtures Containing Zinc," Pence states he obtained blues and purples of varying hues.

In my own experience, I have noted colors to which no reference has been made, so far as I am aware, *viz.*, grays. It was with the object of investigating the influence of various RO combinations on the production of these colors that this study was undertaken.

Experimental

The materials used in this work include the following: Eureka feldspar, Golding cornwall stone, English cliffstone whiting, precipitated barium carbonate, red seal oxide of zinc, calcined magnesite, white lead, oxide of nickel, calcined North Carolina kaolin, Granville flint. All of these were taken from the regular factory stock excepting the calcined magnesite, which was purchased from the Roessler & Hasslacher Chemical Company expressly for this investigation. This was calculated as MgO. The oxide of nickel was a greenish colored powder obtained as a

¹ Received February 27, 1920.

result of calcining the blue oxide. It was considered as NiO for the purposes of this study.

The glaze chosen as the basis for this investigation was similar to the one used by Bryan in his study of the "Action of Chromium Oxide in Glazes Containing Zinc," volume X, of the Transactions of the A. C. S. Its molecular formula is:



The K_2O in these glazes was supplied by both feldspar and Cornwall stone in equivalents of 0.15 of the former and 0.10 of the latter wherever the formula made this permissible. The reason for the use of stone rests on the fact that it reduces the amount of raw clay needed to satisfy the formula. In my experience this reduction of the clay addition has been found beneficial in overcoming the tendency of glazes to draw on the porous wall-tile bisque. Inasmuch as there was no opportunity to have chemical analysis of the various materials made, it was deemed sufficient for the purpose of this study to use the formulas and combining weights for the various materials given in the Manual of Ceramic Calculations, published by the Society.

The content of nickel oxide used was arbitrarily chosen at 0.025 equivalent and was made as a straight addition to the glaze. Lack of time prevented the investigation of larger additions of the coloring oxide, although a preliminary trial indicated some interesting possibilities along that line.

Four series of glazes were made to investigate the influence of the different RO oxides on the colors produced by nickel. The molecular formulas and batch weights of these glazes are given in table 1. In all series, the contents of Al_2O_3 at 0.35 equivalent and SiO_2 at 2.00 equivalent were maintained constant.

Series 1. In this series, consisting of six glazes, the K_2O and CaO were maintained constant at 0.25 and 0.30 equivalents respectively, while the BaO was replaced by ZnO in increments of 0.05 equivalent up to 0.25 ZnO . This, in a measure, overlaps the work reported by Pence, but is included here in order to make comparisons easy and also to check in a way the results he obtained.

Series 2. Again using the base glaze as a starting point, and maintaining the K_2O and CaO constant as in series 1, the BaO was replaced by MgO in increments of 0.05 equivalent up to 0.20 MgO . This affords a direct comparison of the action of zinc oxide and magnesium oxide.

Series 3. Glaze 5. series 1, whose RO content consists of 0.25 K_2O , 0.30 CaO , 0.25 BaO , 0.20 ZnO , was used as a basis for this series.

In the first two members, the K_2O , ZnO and BaO were maintained constant while MgO was increased at the expense of the CaO ; in the third member, another increase of MgO was made at the expense of 0.05 BaO .

Series 4. Desiring to note the effect of PbO on such colors as might be produced in the above glazes, two glazes were made in which the K_2O was replaced by PbO . The starting point for this series was glaze 4, series 3, whose RO content is 0.25 K_2O , 0.20 CaO , 0.20 BaO , 0.20 ZnO , 0.15 MgO . In order to construct these glazes it was necessary to reduce the spar and stone. This was done by reducing the stone to 0.05 equivalent, and the spar from 0.15 to 0.10 equivalent.

Each glaze was weighed separately and ground in small ball mills. The glazes were then dipped on small wall tile ($1\frac{1}{2}$ by $1\frac{1}{2}$ inches) care being taken to get as uniform a coating as possible. The trials were then placed in a sagger containing cones and fired with coal in a commercial downdraft kiln. Cone 4 was down flat and cone 5 just started in this fire. This heat treatment as indicated by the trials was hardly sufficient to mature those glazes of series 1 highest in BaO and those of series 2 where MgO represents BaO . Nevertheless the results show very clearly the colors developed by the various RO oxides. If time had permitted, these trials would have been refired to a temperature which would have brought them to maturity.

Results

Series 1. The color changes developed with the replacement of BaO by ZnO checks Pence's results. The colors vary from a purplish brown in the low ZnO members to a bluish purple in

the higher Zn members. No strong blues were obtained, but Pence shows that this change comes with higher ZnO content than these glazes contain. His blues were obtained with from 0.30 to 0.40 ZnO.

Series 2. As before stated, this series is evidently immature, yet the action of MgO is easily discernible. From the purplish brown of glaze 1, a decided change to gray tones is distinguished with a small content of MgO. Those glazes higher in MgO become successively more gray until a neutral gray is reached with 0.15 and 0.20 equivalent. No particular difference in color is noted with increase of MgO from 0.15 to 0.20 equivalent.

Series 3. The strong fluxing action of the ZnO is evidenced here as all glazes are well matured. Glaze 1, corresponding to glaze 5, series 1, is a purple with bluish tone. Glaze 2 is a mingled purple and gray. Glaze 3 is a nice blue gray somewhat like the French gray. Glaze 4 is a gray of greenish hue. The bluish tint in this series can no doubt be traced to the influence of the ZnO, which is known to produce bluish tints.

Series 4. In this short series the action of PbO is observed. In both glazes the grays are of a decided yellowish tone due, no doubt, to influence of the PbO in producing browns.

Conclusions

In this study, we have demonstrated that grays are obtained from oxide of nickel in the presence of magnesium oxide. This is the point we are desirous of proving and in having done so we feel justified in presenting the results for your consideration.

NOTE.—On page 149, Vol. 14, *Trans. Am. Chem. Soc.*, Pence notes that the familiar nickel brown color was obtained in a glaze of the following composition:



In order to note the effect of larger amounts of oxide of nickel in a glaze of this type, the following experiment was made: Taking the above glaze as a base, nickel oxide was added to it in percentages of its batch weight, beginning with 1% and increasing 0.25% at a time up to and including 3%. The results were in-

teresting. With 1% oxide of nickel, the glaze was bright and of the familiar brown color, but with the next addition of oxide of nickel green flakes began to appear on the surface of the brown color. These green patches became larger and more numerous with increasing amounts of nickel until they completely covered the surface with a content of 3% nickel oxide, and we had a beautiful bright green semi-mat glaze. There seems to be no doubt that in this case the color is due to saturation of the glaze with nickel oxide.

AMERICAN ENCAUSTIC TILING CO.
ZANESVILLE, OHIO.

DISCUSSION

MR. R. H. MINTON: Everyone who has worked with mat glazes for tile, faience and terra cotta is familiar with the effect produced by either BaO or MgO upon colors which usually result in glazes with the RO composed of K_2O , CaO and ZnO. Glazes which the writer has used commercially check the results obtained by Mr. Whitmer. A glaze of the following composition shows the effect of BaO in producing a blue green with NiO:

| | | |
|------------|----------------|-------------|
| 0.20 BaO | | |
| .15 K_2O | | |
| .25 CaO | 0.35 Al_2O_3 | 1.6 SiO_2 |
| .30 ZnO | | |
| .10 NiO | | |

Another glaze of a very similar composition, containing BaO and ZnO, but with an addition of SnO_2 , will turn the color from a blue green to a grey green.

| | | |
|------------|----------------|--|
| 0.20 BaO | | |
| .25 K_2O | | |
| .14 CaO | 0.25 Al_2O_3 | $\left\{ \begin{array}{l} 2.0 \text{ } SiO_2 \\ .1 \text{ } SnO_2 \end{array} \right.$ |
| .35 ZnO | | |
| .06 NiO | | |

The introduction of MgO at the expense of ZnO always gives the greyish tinge as shown by the following glaze, which develops a pale greyish green.

| | | |
|-------------|----------------|--------------|
| 0.30 K_2O | | |
| .35 CaO | | |
| .15 BaO | 0.40 Al_2O_3 | 2.25 SiO_2 |
| .10 MgO | | |
| .10 NiO | | |

No doubt a higher content of MgO would produce a stronger shade of grey.

AUTHOR'S CLOSURE: The discussion by Mr. Minton is interesting and in a measure confirms the conclusions presented in my paper. It further serves to emphasize the necessity for a complete presentation of the conditions under which results are obtained.

In the glazes quoted by Minton, the content of nickel oxide is much higher than used in the glaze study under discussion. In all probability, this is the determining factor in producing the green colors which he reports. In none of the glazes quoted in my paper was there any color resembling green, although in a preliminary experiment on group 1, a content of NiO as high as 0.05 equivalent was used.

Calculating the batch weights for his glaze 1, we have the following: 39.4 barium carbonate, 83.4 feldspar, 25.0 whiting, 24.3 oxide of zinc, 7.5 oxide of nickel, 51.6 clay, 18.0 flint; total, 249.2. From these figures, we find that the nickel oxide content is equivalent to 3% of the batch weight of the glaze. This is interesting in light of the results reported in the note to my paper, wherein 3% of nickel oxide added to an ordinary bright raw lead glaze gave a bright green color. The influence which varying amounts of the coloring oxide may have upon the development of the grey color would form the basis for an interesting investigation.

Mr. Minton's statement that the effect of BaO is to produce a blue-green with NiO is rather surprising. As already stated, I surmise that the green color is due to the high content of nickel oxide and Pence has presented data¹ which seems to demonstrate that the blue from nickel oxide is due to the influence of ZnO. I have many times noted the blue-green color, varying in intensity with the NiO content in glazes with no BaO and high in ZnO.

¹ *Trans. Am. Chem. Soc.* 14.

NOTE ON THE MOTION OF THE STIRRERS USED IN OPTICAL GLASS MANUFACTURE¹

BY E. D. WILLIAMSON AND L. H. ADAMS

The fact that the molten glass has to be stirred constitutes one of the greatest differences between the processes of manufacture of ordinary kinds of glass (plate, bottle, window, and so forth), and optical glass. This stirring is necessary because of the much higher degree of approach to complete homogeneity needed in optical glass. As thorough a mixing as possible must be effected if first grade glass is to be obtained. Fenner² has given a full description of the practical details of the operation.

The stirrers used are necessarily of a very simple nature as the high temperatures of the melting furnaces preclude any possibility of gear arrangements inside the furnaces themselves. In general the stirring is done by means of a clay rod attached at right angles to a water-cooled metal pole which enters the furnace through a small opening above the level of the top of the pot of melted glass. Figure 1 shows a type frequently used.

In deciding on the type of motion to be used in driving the stirrer, and on the relations of the various parts of the mechanism to each other it is necessary to know the nature of the resultant motion of the stirrer itself, due to any given arrangement. This can often be done by constructing small models, but it is both valuable and instructive to have algebraic expressions for the final curves. Such equations often show the relations among the different variable quantities in a way that no models can. It is also difficult if not impossible to find from models the speed of the stirrer at any point; it is equally difficult to find its acceleration, on which depends the necessary driving force, at least to a large extent. These last quantities can readily be found algebraically.

The pots containing the glass are circular, and it is therefore necessary that the motions of the "business end" of the stirrer

¹ Received February 27, 1920.

² Fenner, C. N., *THIS JOURNAL*, 2, 125, 1919.

be roughly circular. In order to secure good mixing it would appear natural to suppose, however, that absolutely uniform circular motion of the stirrer would not be most efficient, as it would tend, at least when the melt is exceedingly liquid, to set up a rotation of the whole contents, a state not so conducive to mixing as a more turbulent motion would be.

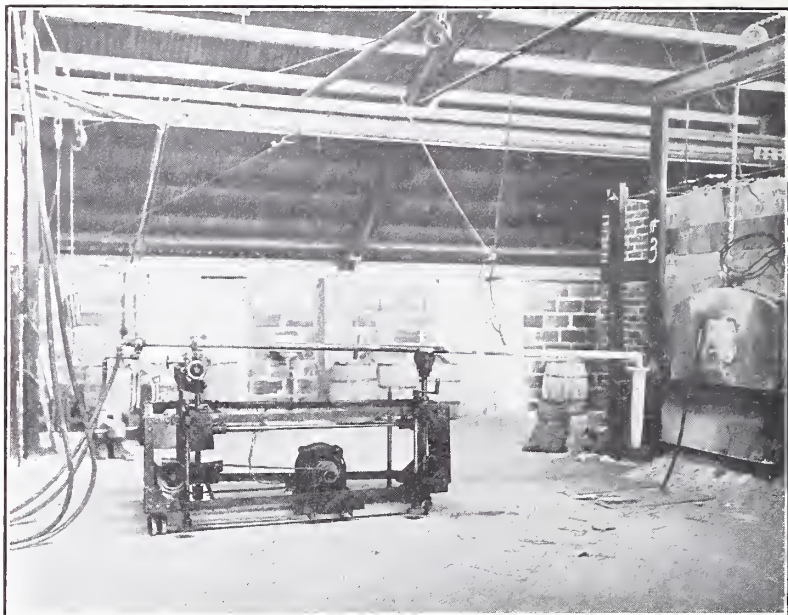


FIG. 1.—One type of stirring machine used in the production of optical glass.

In the following pages we discuss, for two simple cases, the shape of the curve traced by the business end of the stirrer, the variation in the velocity of the stirrer at different parts of the curve, and the area of the curve traced in relation to the surface area of the glass in the pot.

Case 1. (See figure 2.) The cold end B of the stirrer pole BD moves around a circle BB' . At C , a fixed point, the pole moves over a pulley or other arrangement. A is the center of the circle and the arm AB is driven around by a motor and gears at a uniform speed. The motion of D is to be discussed.

If θ be the angle between the pole BD and the fixed line AC , the position of D is fixed by the variable length CD and the angle θ . Let r denote the radius of the circle, c the length AC , l the



FIG. 2.— B represents the butt end of the pole and is constrained to move in a circle with center A . C marks the position of the pulley over which the pole slips. D is where the stirring rod is attached and is the point whose motion is under discussion.

length of the pole and R the variable length CD . Elementary trigonometry shows

$$R = l - c \cos \theta \pm \sqrt{r^2 - c^2 \sin^2 \theta}$$

The double sign is due to the fact that to each angle there correspond two positions of D according as B is on the side of the circle next C or remote from C . If polar coördinate paper is available, the value of R may be used directly to plot the curve resulting from given values of r , c and l . Otherwise let C be the origin and the extension of AC the X axis and it follows that the curve is given by

$$\begin{aligned} x &= \cos \theta \{ l - c \cos \theta \pm \sqrt{r^2 - c^2 \sin^2 \theta} \} \\ y &= \sin \theta \{ l - c \cos \theta \pm \sqrt{r^2 - c^2 \sin^2 \theta} \} \end{aligned}$$

In these expressions the values are taken for values of θ from $\theta = 0$ to $\theta = \sin^{-1} r/c$ and either both $+$ signs or both $-$ signs are used. It is much more convenient to use this form than the somewhat complicated relation between x and y got by the elimination of θ .

Figure 3 shows the curves drawn for various values of the constant involved. From these it is at once obvious that except when c is about equal to $l/2$ the curve is not in the least circular. The broken circle around the middle curve is the circle which just touches it at three points. Its radius is 1.059 times the radius of the circle in which the other end of the stirrer moves. The area covered by this circle is about 10 per cent more than the

area of the figure. The mathematical details of the computations are omitted, as they serve no useful purpose here.

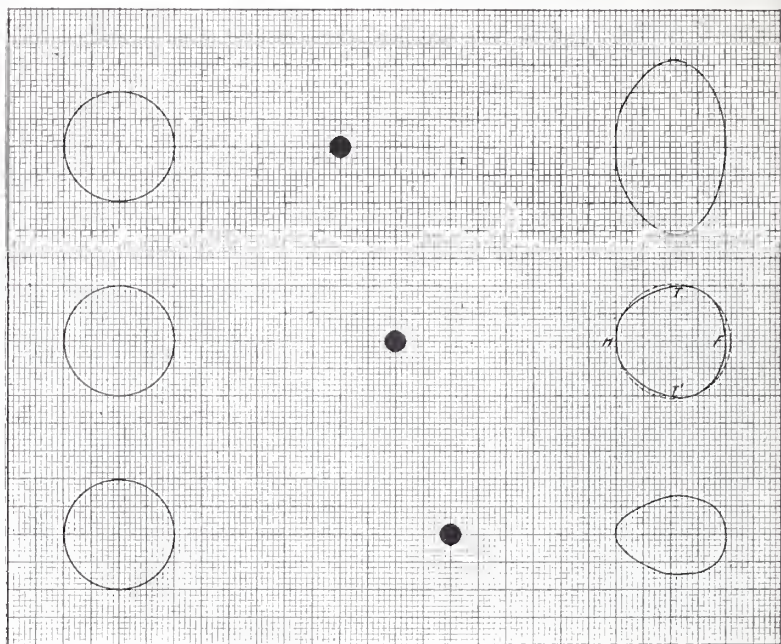


Fig. 3.—The black dots represent the position of the pulley (C in Fig. 2) and the curves at the right hand represent the curves traced by the stirrer (D in Fig. 2) for different positions of the pulley.

As the butt of the stirrer-pole moves round its circle with uniform speed V , the stirring rod moves with variable speed, the formula being rather involved. In the case $l = 10$, $c = 5$, $r = 1$, the maximum speed is $3/2 V$ at F and the minimum is $2/3 V$ at H , while at T and T' the speed is equal to V . In general there are two places (given by $\sin \theta = r/d$) where the speed equals V while the speeds at the points F and H are $\frac{l - c + r}{c - r} V$ and $\frac{l - c - r}{c + r} V$, respectively.

Case 2. A second arrangement which may be used is shown in figure 4. This case differs from the previous one in the motion at *C*. At that point a pin is fixed to the stirrer pole and this pin

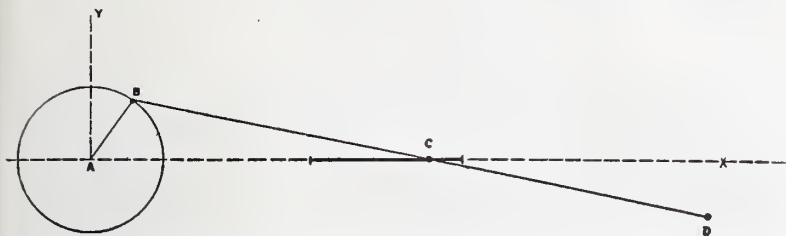


FIG. 4.—*B* represents the butt end of the stirrer as before. *C* is a pin fixed in the pole but sliding in a slot along the axis as marked by the heavy line. The motion of *D* is discussed.

moves in a slot along the line *AX*. In this case if *x* and *y* be the coördinates of *D* parallel to *AX* and *AY*, θ the angle *BAC*, *r* the radius of the circle, l_1 the length *BC* and l_2 the length *CD*

$$x = r \cos \theta + (l_1 + l_2) \sqrt{1 - \frac{r^2 \sin^2 \theta}{l_1^2}}$$

$$y = \frac{r l_2 \sin \theta}{l_1}$$

It is more convenient to use this form for calculation than to eliminate θ (although the elimination is simple) as that leads to an equation of the fourth degree.

Figure 5 shows the form of curves obtained when $r = 1$ and l_1 and l_2 are 4 and 6, 5 and 5, 6 and 4, respectively, in the three cases.

Except when l_1 is about equal to l_2 , the motion is far from circular. Round the curve for $l_1 = l_2$ the circle is drawn which touches the curve at three points. This curve has a radius = 1.052. For this type of motion the areas of the curves described are easily evaluated, as they are obtained by multiplying the area of the circle, in which the butt moves, by l_2/l_1 . In the case where $l_1 = l_2$, the area of the curve therefore equals the area of the circle and is about 10 per cent less in area than a circle of radius 1.052.

The speed of the motion is more uniform in this case than in the previous one. There are as before two places where the speed is equal to that in the circle, namely, the points where

$\cos \theta = 0$, *i. e.*, the points where the radius arm is at right angles to the line of centers. When $l_1 = l_2$ there are two other points of equal speed, namely, where $\sin \theta = 0$ or the points where the radius arm coincides with the line of centers; in general the speed at these points = $l_2/l_1 \times$ speed in circle.

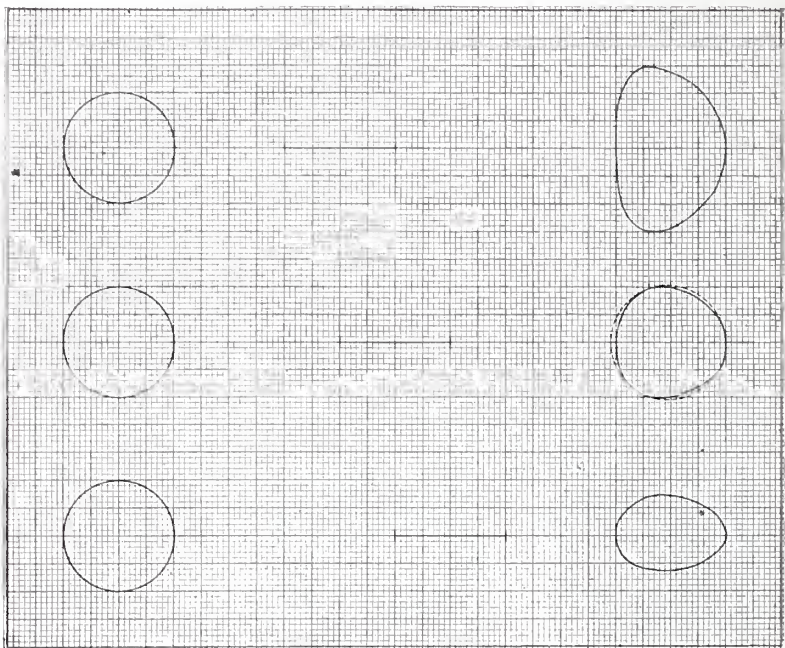


FIG. 5.—The heavy lines represent the slot in which C (fig. 4) moves. The curves at the right hand represent the curves traced by the stirrer (D in fig. 4) for different positions of the pin (C) in the pole.

It would seem that the last arrangement, with $l_1 = l_2$, gives the most satisfactory results compatible with such simplicity of design. If a true circular motion of the business end were needed it would be a simple matter to have a cam made on the model of one of the curves and to cause the cold end to describe that figure instead of a circle. (The analysis of the problem would then be reversed and the business end would describe the circle.) This could be carried out with equal ease, using either type of arrange-

ment. It could also be carried out with different length ratios and this might be convenient for reasons connected with available space and the distance into the furnace which must be reached.

Fenner in the paper cited stated that the maximum convenient radius of the butt circle was seven inches when pots were being used whose inside radius was certainly more than twelve and a half inches. In view of the discussion just given, even allowing an ample figure for the thickness of the stirrer, there should have been no danger of hitting the pot wall using at least a nine inch circle. At the same time he calculated the speed of the motion of the butt round its circle and took that as the speed of the stirrer through the glass. The formula developed from the path equation given in this paper suggests that the maximum speed was about one-fifth greater than this, while the minimum was correspondingly less.

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CARNEGIE INSTITUTION OF WASHINGTON,
February 1920

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

CERAMIC ABSTRACTS

General

The commercial application of electrical osmosis. J. S. HIGHFIELD, W. R. ORMANDY AND NORTHALL. *Pottery Gaz.*, **45**, 775-777 (1920).—The addition of a small amt. of alk. to a suspension of clay in water results in the suspension of clay particles in water while pyrites, mica, free silica and other impurities settle to the bottom. Fine particles which do not settle may be removed by the osmotic process. Bodies which remain in suspension and tend to move toward the cathode, require an electrolyte of an acid character to bring about dispersion or peptization, but bodies which tend to move to the anode require an alk. electrolyte to cause dispersion. Osmosed fire-clays are entirely free from pyrites and goods made therefrom are not subject to green stains when glazed. By the use of fine osmosed kaolin, chem. porcelain has been produced of the highest quality, the body being made of pure kaolin, which, owing to the fineness of the particles, completely vitrifies. There is also a better locking of the glaze to the body by fine sillimanite crystals, which form on firing and penetrate the glaze. In clays themselves, the extremely fine particles could be separated from the coarser. Another application is in the electro-osmotic filter press. The press consists of a series of chambers into which the suspension is fed under a head of 10 feet, sufficient to ensure a rapid filling of the chambers. The chambers are closed on both sides by filter cloths in the ordinary way, but the cloths are held in position by perforated or grooved metal, carbon or other conducting plates, one of these plates forming the cathode and the other the anode. An electric pressure of 20 to 100 volts, depending upon the substance, is necessary. In this press very fine material which would clog up the ordinary filter press, can be dewatered. H. Jackson stated that in using a well-known clay for a muffle he was only able to get 24 hours' service from the same. By treating this clay by osmosis he made muffles from which he got 10-15 times the service. Ormandy stated that a muffle made of osmosed clay lasted 13 journeys whereas the muffles made of the same clay, not treated, would never last more than 3 journeys. With the finest English china clay which had been treated with 87 tons of water in order to wash 3 tons of clay, it was still possible to separate 7 per cent material from the clay. H. G. SCHURECHT.

An efficient oil burner. W. J. JONES. *Pottery Gaz.*, **45**, 767 (1920).—A high pressure oil burner adapted for cheap fuel consisting of 50 per cent creosote and 50 per cent pitch is described. The fuel is kept in storage tanks where it is kept heated to 100° F. by means of steam coils. The storage tanks are about 10 feet above the burner and an air pressure of 60 lbs. is used.

The oil is introduced by means of a drip feed. An accumulator was resorted to in order to pass air through the burner, thus atomizing the oil. An annulus is on the front of the burner into which air is admitted at the same pressure. Around the face of the burner are serrations through which the air is passed in a solid ring, so as to prevent the atomized oil from spreading too quickly. With this burner a narrow stream of atomized oil and high pressure air pass well into the furnace. The results were so efficient that with a single burner of this type a furnace 15×8 feet, containing eight glass pots, could be kept at a constant flame temp. of 1500° C. The oil consumed was about 16.8 gals. per hr. More complete combustion can be obtained by oil firing than with lump coal.

H. G. SCHURECHT.

PATENTS

Dryer. WARREN B. HUTCHINSON. U. S. 1,338,731, May 4, 1920. A rotary imperforated dryer having a screw feed for material therein, the screw being perforate for the passage of air, and means of forcing a drying medium through the screw and dryer in the opposite direction to the feed of the screw.

Process for drying materials. HUGH B. LOWDEN. U. S. 1,339,771, May 11, 1920. A method of mechanically drying materials consisting in delivering the material upon hearth at one end, and advancing the material over the hearth toward the other end by repeatedly cleaving it in a substantially vertical direction and pushing it through a small part of the length of the hearth.

Method for molding plastic materials. DIRK SHANSTRA. U. S. 1,340,452, May 18, 1920. A process of making balls from plastic material which consists in first bringing the material to an elongated ball shape on one mold and then finishing it to its spherical shape in another mold by pressure longitudinally of its major axis.

Drying kiln. CLIFFORD A. CUTLER. U. S. 1,341,884, June 1, 1920. A kiln having walls, a ceiling and false ceiling, a plurality of supports arranged above the floor, air intake in the ceiling, the false ceiling being formed, with air opening, means for regulating the openings in the false ceiling, means for providing a plurality of air blasts arranged in the space between the floor and the supports, and air exhaust duct opening near the bottom of the kiln.

Air-conditioning apparatus for drying-kilns. HERVEY N. ANDREWS. U. S. 1,343,894, June 22, 1920. In a drying kiln, means for adding to the humidity of the air, means for taking moisture from the air, and synchronized means including a control element governed by the degree of humidity in the air for controlling both of the means.

Drying plant. PRLADE BARDUCCI. U. S. 1,344,163, June 22, 1920. Apparatus for drying materials in a drying room, comprising a plurality of supports arranged longitudinally in the room, a ventilating device embodying

a casing having mouths in its walls facing the supports and ventilating means located in the casing and means for reciprocating the casing in the room along the supports, the ventilating means producing simultaneously draft air streams and blast air streams between the supports.

Drying apparatus. SIJTSE HERO MEIUIZEN. U. S. 1,344,241, June 24, 1920. The apparatus comprises an open ended drying chamber, means for heating and simultaneously creating a draft through the chamber, a frame movable vertically within the drying chamber, trays carried by the frame, and receptacles supported by certain of the trays, the trays being arranged to direct the draft within the drying-chamber to the top of the receptacles.

C. M. SAEGER.

Whiteware and Porcelain

Some pitfalls in body making. A. HEATH. *Pottery Gaz.*, 45, 782-783 (1920).—In selecting a ball clay the usual method is to mold a test piece and measure the contraction upon drying and after it has been fired. If the contraction is normal and the color as good as that of the clay being used the potter feels justified to use it. These tests are not sufficient. For example, ball clays vary in moisture content from 8-18 per cent which would have a bearing upon its value. Others contain carbon varying from 8-9 per cent. Again some clays contain considerable sand. The correct way to test a ball clay is to test it for fineness by passing it through a fine screen, ignite it to determine its carbon content and analyze it to determine its chemical compn. Stone varies considerably in alks., the hard purple type contains 8 per cent, while the buff contains about 3.5 per cent. The substitution of buff stone for the purple stone has caused considerable trouble. Flint is also a source of trouble, there being two varieties, boulder and chalky flint. By the introduction of lime into the body with chalky flint, crazing may occur. Greater accuracy in mixing is emphasized and weighing should be done to $1/2$ oz. Owing to the expansion of flint upon calcination an excess would cause peeling. The use of measuring is inaccurate, since a variation of $1/8$ inch may make a difference of $2 1/2$ per cent. For judging the fineness screens alone are not sufficiently accurate. Where Na_2SiO_3 is used in casting the ap., fr. should be measured from time to time as this often varies. In making bone china one of the common faults is green china caused by an excess of clay. Since the range of compn. for good bone china body is often small, this trouble may be often traced to the fact that the clay in storage has dried considerably and consequently too much is added to the body.

H. G. SCHURECHT.

Recent achievements in pottery casting. BY A MEMBER OF STAFF. *Pottery Gaz.*, 45, 773-774 (1920).—Seven or eight yrs. ago A. Leonhardi of Schwepnitz, Saxony, used the casting process in connection with the manuf. of large glass pots. Dr. Weber also obtained a patent on an electrolytic process for casting glass pots, 28 inches deep and 24 inches in diameter,

which were cast in a mold constructed of plaster and iron. The time occupied for casting by this method was only 1 or 2 minutes. Until recently, however, British glass pot makers have looked askance at the casting process. Later B. J. Allen, of Stoke-on-Trent, developed a process of casting by vacuum and pressure, which promises to revolutionize the present system of hand manufacture. By the casting process it is possible to produce a glass pot of 36 inches in diameter in as many days as it now takes months by the hand-building process. On May 27, 1919, the first fireclay gas retort ever produced in England was exhibited. It had a diameter of 2 feet, 4 inches, a thickness of 2 inches and a length of 5 feet. A two-piece plaster mold with a core was used. The molds which are about 3 inches thick, are reinforced by a casing of wood. The two parts when fitted together are held in place by an outer frame of wood bound with iron hoops. The mold is filled with a slip by means of funnels. After casting the ware is left 18 hours, after which the core is removed and the outer molds are taken off.

H. G. SCHURECHT.

Glass

The development of various types of glass. Part I. The interaction of silica with the oxides of sodium and potassium. Part II. The interaction of silica, lime and sodium oxide. Part III. The interaction of silica, lime and potassium oxide. Part IV. The interaction of silica, lime and the oxides of sodium and potassium. Part V. A comparison of the soda-lime-silica and the potash-lime-silica glasses. C. J. PEDDLE. *J. Soc. Glass Technology* 4, 3-107 (1920).—The data summarized in these excellent papers are the result chiefly of researches by the author during the past four years in connection with the production of optical glass. A great mass of data is presented. *Conclusions regarding soda-silica glasses.* Experiments with glasses containing 17 to 50 per cent soda showed: (1) with over 75 per cent silica and under 25 per cent soda required temperatures above 1300°C for their production; (2) glasses with less than 70 per cent silica and more than 30 per cent soda all melted down below 900°C ; (3) glasses with over 28 per cent soda were totally insoluble in H_2O , indicating that no free silica molecules were present; (4) increasing soda increased pot attack; (5) glasses with 28 to 40 per cent soda did not devitrify. Below 28 per cent soda, the silica tended to separate out, and above 40 per cent soda the crystallization of sodium silicates took place readily; (6) glasses with over 20 per cent soda weathered rapidly; (7) density increased with increase in soda, but above 40 per cent the changes were small. The density of silica was found to be 2.220 and of soda (Na_2O), 2.625; (8) the refractive index increased with increase in soda, but the rate of increase fell more rapidly than in the case of density; (9) none of the soda-silica glasses would be of use for optical work. Low durability rules out all above 17 per cent soda and the low soda glasses easily become devitrified. *Conclusions regarding potash-silica glasses.* Experiments with 24 to 61 per cent potassa (K_2O) showed: (1) Such glasses

are difficult to produce and can not be preserved except in a dry atmosphere, free from CO_2 ; (2) durability decreased and solubility increased with increase in potassa; (3) glasses with over 30 per cent potassa were totally soluble in water; (4) compared with equivalent soda glass it was noted that the potash glasses (a) were easier to melt; (b) showed less color, (c) were less durable, and (d) between 20 and 40 molecules per 100 of silica the potash glasses gave a higher index of refraction and greater total dispersion. This may be true for the whole series but the data were not obtained. *Conclusions regarding soda-potash glasses.* Experiments with glasses containing both soda and potash showed that properties were intermediate between those of soda and of potash glasses. *Conclusions regarding soda-lime-silica glasses.* Experiments were made with two series with molecular ratios of 100 SiO_2 , 40 Na_2O , x CaO and 100 SiO_2 , 20 Na_2O , x CaO . The results showed: (1) All glasses of both series could be melted at temperatures above 1300° and all showed attack on the pot; (2) increase in either lime or soda increased pot attack, the soda being more corrosive than the lime; (3) because of volatilization and pot attack large melts show higher index of refraction than small melts; (4) density increased with additions of either lime or soda, the lime showing greater increases per molecule added; (5) density increases per molecule of lime added were not constant. The increase was greatest with low soda and the effect lessened as the lime content increased. The lessening effect of increasing lime was greatest with high soda glasses; (6) refractive index increased with increases in lime or soda, more with lime than with soda, the rate of increase falling with high lime content. With high soda this fall in rate is greater than with low soda glasses; (7) where molecular lime-silica ratio was the same, the glass with the higher soda content had the higher index and the higher total dispersion; (8) total dispersion increased with increases in lime or soda; (9) the dispersive reciprocal decreased continually as the index for the D line increased; (10) increasing lime or soda lengthened both ends of the spectrum, the blue more than the red, and the lengthening effect of lime was greater in the series with the lesser soda; (11) with over 72 per cent SiO_2 there is a tendency to vitrify; (12) glass of this type with over 10 per cent lime divitrifies easily if the soda is over 20 per cent. With soda under 15 per cent, the lime may be increased up to 15 per cent before showing devitrification; (12) solubility in water increased with increases in soda and decreased with increases in silica or lime; (13) durability is therefore increased by adding lime or silica and lowered by adding soda; (14) all glasses with over 15 per cent soda became dim on long exposure to air; (15) none of these straight soda-lime glasses is suitable for first-class optical work. They either are not durable or they divitrify too easily; (16) for jars, bottles, etc., a glass containing about 100 SiO_2 , 20 Na_2O , 20 CaO , is useful. Lime even up to 14 per cent is satisfactory. The modern tendency is to use too little lime; (17) glasses with over 16 per cent soda are not durable enough to warrant their use for food containers; (18) if soda is not above 15 per cent and silica is about 72 per cent there is practically no tendency to divitrify; (19) probably

the best batch of this type is sand, 720; soda ash, 260; limestone, 230 parts. If salt cake is used, substitute 350 parts for the 260 of soda ash and add charcoal or powdered coal, 1 part to every 20 of salt cake. *Potash-lime-silica glasses.* Series similar to the soda-lime-silica glasses were studied. The first series was based on 100 SiO_2 , 40 K_2O , x CaO and the second series on 100 SiO_2 , 20 K_2O , x CaO . Conclusions: (1) All of the glasses can be melted above 1300°C ; (2) all attacked pot clay; (3) density and index of refraction both increased with additions of lime or potassa (K_2O), lime having the greater effect per molecule added; (4) total dispersion increased with additions of lime or potassa, the rate of increase being greater with the lower potassa content; (5) dispersive reciprocal was higher in the series with lower potassa and decreased with increasing lime or potassa; (6) with potassa above 34 per cent devitrification took place readily; (7) solubility decreased with increase in lime or silica but increased rapidly with increases in potassa; (7) none of the glasses are good optical glasses. *Soda-potash-lime-silica glasses.* Two series of glasses were made, 100 SiO_2 , 20 Na_2O , 20 K_2O , x CaO and 100 SiO_2 , 10 Na_2O , 10 K_2O , x CaO . Conclusions: (1) Density and refractive index increased with increase in lime or alkali, the effect of lime being greater per molecule added; (2) dispersive reciprocal was higher in the series with the lower alkali and decreased as lime or alkali increased; (3) in the first series glasses with over 9 per cent lime were easily devitrified; (4) in the second series lime could be increased to 13 per cent without devitrification; (5) solubility in water decreased with increases in lime but increased rapidly with increases in alkali; (6) none of the glasses shows first-class durability but glasses about 100 SiO_2 , 10 Na_2O , 10 K_2O , 20 CaO , might be used in optical instruments, especially if protected. The index for D line is about 1.25, and dispersive reciprocal about 59.4. The durability is about like Schott silicate crown No. 0.337. *Comparison of the above types.* The comparisons apply to glasses of the molecular type 100 SiO_2 , y R_2O , x CaO , where R_2O may be Na_2O or K_2O or equimolecular Na_2O - K_2O mixtures, y varying between 20 and 40 molecules and x between 5 and 40 molecules. All comparisons are based on molecular ratios. Conclusions: (1) Density, refractive index and total dispersion is higher in the soda than in corresponding potassa glasses; (2) the soda glasses have the lower melting points; (3) devitrification was more easily induced in the soda than in the potassa glasses; (4) with high lime glasses increase in silica tended to prevent devitrification; (5) glasses which tended to deposit silica were improved by adding lime; durability of the soda glasses was better than that of the potassa glasses (from the standpoint of percentage weights the reverse is true); (6) no glass of the type 100 SiO_2 , 40 R_2O , x CaO is of practical use, all being too soluble; (7) glasses of about 100 SiO_2 , 20 R_2O , 20 CaO are of value—all other glasses in the series are of little or no value on account of devitrification or failure in weathering; (8) this typical formula (which may be written 5 SiO_2 , 1 R_2O , 1 CaO), is believed to be better for lime-alkali-silica glasses than the Benrath formula, 6 SiO_2 , 1 R_2O , 1 CaO so commonly used.

C. H. KERR.

A suggested improvement in the manufacture of glasshouse pots. C. W. THOMAS. *J. Soc. Glass Technology* 4, 107-111 (1920).—Covered pots might be made in two sections, top and bottom, and to obviate the possibility of an open joint, a cushion of asbestos rope may be fitted at the joint, each part being grooved to hold the rope. The author suggested this because of the success of a similar experiment at nearly as high a temperature in another industry. There the rope lasted seven years. The chief advantage of the two-section pot is in permitting tamping the interior surface to make it denser and tougher.

C. H. KERR.

The optical properties of some lime-soda glasses. J. R. CLARKE AND W. E. S. TURNER. *J. Soc. Glass Technology* 4, 111-5 (1920).—The series of glasses investigated ranged from 2 Na₂O, 6 SiO₂ to Na₂O, CaO, 6 SiO₂. Conclusions: (1) The refractive index for the D line is practically an additive property of the composition; (2) replacing each 0.1 molecule of soda by 0.1 molecule of lime increased the refractive index, on the average, by 0.0020; (3) there is very little change in total or partial dispersions or in dispersive reciprocal throughout the series; (4) the ultraviolet absorption band is fairly constant at about wave length 0.295 microns. The glasses are very transparent to ultraviolet light.

C. H. KERR.

The thermal expansion of magnesia-containing glasses. S. ENGLISH AND W. E. S. TURNER. *J. Soc. Glass Technology*, 4, 115-20 (1920).—Expansions were determined for a temperature range of 25-90° C. The glasses ranged from 0 to 9 per cent magnesia, from 24 to 12 per cent soda and from 74 to 78 per cent silica. Coefficient of expansion is an additive property of the composition. Replacing soda by magnesia causes rapid lowering of expansion. Magnesia is much more effective than lime in reducing expansion, but is not as abnormal in this respect as claimed by Schott. New factors, superior to the Schott factors, are given.

| | Schott factors | English and Turner |
|------------------------|----------------|--------------------|
| SiO ₂ | 0.8 | 0.05 × 3 |
| Na ₂ O..... | 10.0 | 4.32 × 3 |
| CaO..... | 5.0 | 1.63 × 3 |
| MgO..... | 0.1 | 0.45 × 3 |

The Schott factors are for cubical expansion. The English and Turner factors are for linear expansion and therefore must be multiplied by 3 for comparison with the Schott figures.

C. H. KERR.

The comparative effects of soda and potash in lead glass for table ware. F. W. HODKIN AND W. E. S. TURNER. *J. Soc. Glass Technology*, 4, 120-5 (1920).—Three series of glasses were studied.

| | Series I | | | Series II | | | Series III | | |
|-------------------|----------|-----|-----|-----------|-----|-----|------------|-----|-----|
| | 1 | 2 | 3 | A | B | C | D | E | F |
| Sand..... | 504 | 504 | 504 | 500 | 500 | 500 | 500 | 500 | 500 |
| Red Lead..... | 224 | 224 | 330 | 330 | 330 | 330 | 330 | 330 | 330 |
| Borax..... | 10 | 10 | 10 | ... | ... | ... | 10 | 10 | 10 |
| Soda ash (95%).. | 144 | 72 | ... | 134 | 66 | ... | 134 | 67 | ... |
| Sodium nitrate.. | 42 | 21 | ... | 21 | 10 | ... | 20 | 10 | ... |
| Potash..... | ... | 94 | 188 | ... | 83 | 165 | ... | 83 | 165 |
| Potassium nitrate | ... | 25 | 50 | ... | 13 | 25 | ... | 13 | 25 |

Conclusions: (1) The lead-soda glasses melt most readily and the lead-potash least readily; (2) the lead-soda-potash glasses, with equivalent proportions of soda and potash, fine more readily than either of the others; (3) the lead-potash glasses are the most viscous and the lead-soda the least; (4) color due to pot corrosion is worst with soda glasses and best with lead-potash; (5) the presence of about 2 parts of borax per 100 of sand makes lead glasses notably more durable; (6) a mixture of alkalis is preferable for all round purposes, and mixed alkali glasses are more durable than with either alkali alone.

C. H. KERR.

The density of soda-lime glasses. S. ENGLISH AND W. E. S. TURNER. *J. Soc. Glass Technology*, 4, 126-8 (1920).—Results as indicated in the table show that substituting lime for soda increases density. The Winkelman and Schott density factors used in calculating density are obviously too low and

| Glass No. | CaO Per cent | Density observed at 20° C | Density calculated W. & S. factors |
|-----------|-----------------|------------------------------|---------------------------------------|
| 1..... | ... | 2.4353 | 2.383 |
| 2..... | 1.57 | .4384 | 3.383 |
| 3..... | 2.63 | .4416 | 2.389 |
| 4..... | 3.79 | .4462 | .391 |
| 5..... | 4.54 | .4507 | .401 |
| 6..... | 6.22 | .4602 | .419 |
| 7..... | 7.56 | .4650 | .418 |
| 8..... | 8.15 | .4682 | .413 |
| 9..... | 9.26 | .4757 | .419 |
| 10..... | 10.40 | .4850 | .429 |
| 11..... | 11.63 | .4904 | .431 |
| 16..... | 18.06 | .5866 | .523 |
| 17..... | 17.35 | .5547 | .490 |

require revision.

C. H. KERR.

The preservation of glass furnace refractories by water-cooling. E. B. CHRISTMAS. *J. Soc. Glass Technology*, 4, 128-38 (1920).—The Knox system is described.

C. H. KERR.

PATENTS

Cutting-off device for glass-drawing apparatus. WILLIAM E. STANDLEY. U. S. 1,338,109, April 27, 1920. A cooling and cutting-off device for glass cylinders, comprising an annular casting provided in its body with an annular gas conduit and a passage to receive a cooling medium to cool the glass that attaches to a drawing bait, the gas conduit being arranged to be attached to a gas supply and having a plurality of outlets for directing a series of gas jets against the periphery of the glass cylinder.

Apparatus for delivering mold charges from glass-furnaces. SCOTT DAVIDSON AND ALEXANDER L. SCHRAM. U. S. 1,338,214, April 27, 1920. The apparatus provided with a discharge orifice, through which molten glass may flow by the action of gravity, an imperforate plunger projecting into the furnace and adapted to completely close the upper end of the orifice, the peripheral portion of the lower face of the plunger, being flat and adapted to form a close joint with the upper end of the wall surrounding the discharge orifice, the plunger adapted on its downward stroke to assist the action of gravity in the flow of glass through the orifice, and on its upper stroke to retard the flow.

Process and apparatus for the production of sheet-glass. GEORGE B. STANTON. U. S. 1,338,261, April 27, 1920. The process consists in pouring the molten glass in a sheet of uniform thickness, moving a collecting medium downwardly past the point at which the glass is poured, whereby to collect by adherence to the said medium the first poured portion only of the sheet, and as the sheet is formed through hardening of the glass leading the sheet downwardly by the collecting medium, and subsequently disassociating the collecting medium from the sheet; also a container for molten glass arranged at one side to discharge the glass in a sheet of uniform thickness by pouring, means for adjusting the container to pour the molten glass therefrom, bait rods, and means for supporting and moving the bait rods downwardly past and in close proximity to the pouring side of the container.

Glass shaping or blowing machine. ARTHUR WILZIN. U. S. 1,338,604, April 27, 1920. In a suction head for glass blowing and molding machines, the combination with a neck mold, of a movable plunger adapted to coöperate therewith, a spring adapted to normally hold the plunger out of coöperative relation with the neck mold, a parison mold also adapted to coöperate with the neck mold, a pneumatic piston for moving the plunger into coöperative relation with the neck mold, the piston being actuated against the tension of a spring by the suction existing in the parison mold only during the latter part of the filling thereof, and means for adjusting the tension of the spring to determine the stage in the filling operation at which the plunger is moved into coöperative relation with the neck mold.

Method of and apparatus for manufacturing glassware. ERICK P. LINDAHL. U. S. 1,338,941, May 4, 1920. The combination of a carrier, blank supports

thereon, scoring means for the outer end of the blanks, supported by the blank supports, also heating means for the outer ends, and also chilling means for the outer ends, the heating means and chilling means positioned with relation to a carrier to cause coaction between outer ends and scoring means.

Drawing glass sheets. HARRY G. SLINGLUFF. U. S. 1,339,229, May 4, 1920. A tank adapted to contain a body of molten glass, with a means at each side thereof for maintaining the position of the edge of a sheet of glass being drawn comprising a body of refractory material lying beneath the surface of the glass and provided on its upper side with a groove whose inner portion constitutes the locus of generation of the edge of sheet, and a chilling bar extending between said means.

Glass drawing and cutting mechanism. IRVING W. COLBURN. U. S. 1,340,262, May 25, 1920. Drawing a sheet of plastic glass, bending it and feeding it in a horizontal plane until it is cooled to a frangible state also with a mechanism for scoring a sheet of glass of cooperating means for fracturing the sheet along the scored line.

Sand grading apparatus for glass grinding machinery. JOHN WILLIS. U. S. 1,342,038, June 1, 1920. The apparatus comprises a primary grader adapted to receive water and abrasive, a secondary grader consisting of a series of successively arranged partitioned compartments, a means for supplying sand and water from primary grader to the first compartment of the secondary grader, including means to remove water and sand from compartments.

Removing of glass from furnaces. ENOCH T. FERNGREN. U. S. 1,342,042, June 1, 1920. The method consists in creating a directionally predetermined and constant flow of refined glass of homogeneous fluidity, maintaining the constancy of the fluidity in the glass and taking successive gathers from untouched portions to the surface of flowing glass.

Pressing-plunger mechanism for glass machine. WILLIAM J. MILLER. U. S. 1,342,056, June 1, 1920. The mechanism comprises a reciprocating member, a yoke mounted on the member and capable of rocking in relation thereto, grasping fingers pivotally attached to the yoke and depending below the member, resilient means for spreading said fingers apart, a pressing plunger impinging against the under surface of the member, also with a means for locking said fingers into engagement with sand pressing plunger.

Glass-shaving apparatus. JAMES H. ALLAN. U. S. 1,342,080, June 1, 1920. The apparatus comprises a buoyant ring member and a top stone above the ring member and contracting therewith, the superposed contacting faces of the top stone and ring member being provided with annular interengaging portions capable of retaining glass seal separated from the bath of molten glass, the contiguous faces being flared from the interengaging portions to the peripheries to permit the access of sufficient heat to the glass seal to maintain the glass in molten condition.

Glass annealing furnace. MAURICE A. SMITH. U. S. 1,342,233, June 1, 1920. A furnace with an annealing chamber inclosed with flues formed in sides and top around chamber with a series of checker-work chambers at the bottom of the furnace communicating with the flues, including opening for delivering air and gas to the checker-work chambers and a stack with which flue communicates.

Reinforced glass and process of making the same. AEON FRANCOIS MASCART. U. S. 1,342,267, June 1, 1920. The process of making non-scatterable glass which comprises applying to a sheet of glass successively a solution of gelatin and a solution of cellulose material, at least one of the solutions containing a solvent which has a solvent action upon both the gelatin and the cellulose material.

Laminated glass. MARSHALL W. GLEASON. U. S. 1,342,282, June 1, 1920. Glassware comprising a plurality of laminae one of which is a distinctive color, while the others are of a neutral character as to color, but different from each other.

Blown glass vacuum brick. ALFRED E. D'HARLINGUE. U. S. 1,342,404, June 1, 1920. A blown glass brick of rectangular form having a tapered circular tenon at one end, a tapered circular pocket at its other end and having in its upper and lower walls longitudinally-extending mortar-receiving pockets that are relatively small in proportion to the contact surface between the upper and lower surfaces of abutting blocks, whereby a much larger amount of transparent surface is obtained than the surface covered by the mortar.

Apparatus for making sheet-glass. JOHN C. CROWLEY. U. S. 1,342,533, June 8, 1920. A receptacle for containing a prepared mass of molten glass, means, including an endless metal belt carrier and two draft drains for drawing a continuous sheet of glass from the mass of glass in the receptacle, the metal belt carrier being the means for bending the sheet, the means for supporting and carrying the sheet and the means for flattening the sheet, the metal belt carrier continuously contracting the sheet of glass from the moment that the sheet starts to bend until it is sufficiently flattened and set for the lehr, gripping chains for holding under tension a desired vertical length of the sheet's edge for maintaining a predetermined width of the sheet drawn, and means for heating a lateral portion of the bottom of the receptacle beneath the sheet source.

Machine for making hollow glass. GUSTAVE A. LEIMAN. U. S. 1,342,821, June 8, 1920. A machine comprising a vertically movable glass tube carrier and progressively operating means for heating the tube, drawing the tube to form a bulb and neck thereon, blowing the bulb, sealing the neck and tube and cutting the neck from the tube.

Process for ladling glass. HARRY F. HITNER. U. S. 1,342,960, June 8, 1920. The process consists in dipping the glass from a body of molten glass

in a metal ladle so that the glass next to the ladle is chilled, forming a plastic skin or pocket, depositing the pocket with its content of molten glass in a receptacle with the pocket intact and in contact with the walls of the receptacle and still carrying its content of molten glass, and drawing a glass article from the molten glass in the pocket.

Glass-discharging device. SYDNEY L. SEARS. U. S. 1,343,183, June 8, 1920. A device consisting of a furnace having two superposed chambers having vertically aligned glass outlets, the upper chamber having a glass inlet, and independent means for heating the two chambers.

Toric-lens grinding machine. RUDOLPH H. BECK AND RUDOLPH J. BECK. U. S. 1,343,492, June 15, 1920. In a lens grinding machine a driving shaft, lens blocks rotated thereby, a yoke, posts on which said yoke is swingingly supported, means to adjustably support the posts, grinding laps carried by the yoke, and means to operatively connect the yoke with the driving shaft to effect the oscillation of the yoke.

Apparatus for supplying and grading abrasives to glass-grinding machines. JAMES W. CRUIKSHANK. U. S. 1,343,710, June 15, 1920. This covers the combination of a collecting receptacle in position to receive the abradant material and water discharged from the grinding mechanism, the receptacle having at its intake portion a plurality of preliminary grading devices through which the material passes into the receptacle and which separate and deliver the coarser material into the receptacle, and a secondary grader arranged to receive a constant volume of flow from the preliminary grading devices.

Supplying and grading sand to glass-grinding machines. JAMES W. CRUIKSHANK. U. S. 1,343,711, June 15, 1920. This describes an apparatus for supplying and grading abrading material to glass grinding machines by means of a series of grading pits.

Method of manufacturing decorated articles of glass with colored figures in the glass mass. ALBERT AHLIN. U. S. 1,343,806, June 15, 1920. The method consists in etching figures upon a colored glass layer, applying thereon an outer layer of uncolored glass and fusing the contiguous surfaces together, thereby filling up the etching.

Manufacturing ruby glass. MAX METH. U. S. 1,344,141, June 22, 1920. The method consists in mixing with the ordinary transparent glass ingredients a suitable quantity of sulphate of antimony and oxide tartar.

C. M. SAEGER.

Refractories

Resistance of zirkite to slag corrosion. ANON. *Min. Foote-Notes*, May-June, 2-8 (1920).—The effect of different materials were tested in zirkite crucibles. It was found that zirkite withstands very well the following materials: (1) The more acid slags containing manganous and ferrous oxides,

such as bessemer converter slags, puddling furnace slags, etc.; (2) glass of various kinds; (3) cobalt-nickel speiss, and (4) ladle slags that are not basic. The following materials attack zirkite moderately: (1) Ladle slags which are basic; (2) iron oxide; (3) copper oxide; (4) portland cement, and (5) litharge. The following materials destroy zirkite crucibles rapidly: (1) Iron sulphide; (2) sodium carbonate; (3) sodium hydroxide, and (4) fluorspar or cryolite. The experiments showed one important limitation in the use of zirkite, namely, the presence of fluorides or fluorine vapors. These are very destructive, particularly fluorine or vapors of hydrofluoric acid. Such vapors cause a peculiar swelling and sponginess in bricks or crucibles. H. G. SCHURECHT.

The corrosion of coke oven walls. H. V. THOMPSON. *Pottery Gaz.*, **45**, 770 (1920).—Highly aluminous clays developing a large proportion of sillimanite are much more resistant to salt attack than the ordinary fireclay brick. There seems to be possibilities in the use of aluminous fire-brick in the construction of coke ovens. The method of making silica brick greatly influence their serviceability in coke ovens. H. G. SCHURECHT.

The analysis of zirconium minerals. H. V. THOMPSON. *Pottery Gaz.*, **45**, 767 (1920).—In the analysis of Zr ores two main difficulties are encountered, namely, (1) raw Zr ores and products manufactured therefrom are not easily decompd., and (2) the separation of Al from Zr is not readily effected. It was decided to make use of the fact that after fusion with NaO_2 and decomposition of the melt with water, the residue contains all Fe, Ti and Zr in the form of oxides, together with some of the SiO_2 , while the whole of the Al and the remainder of the SiO_2 is contained in the filtrate. This process possesses the advantage that Zr and Al are automatically sepd. during the process of decomposing the sample. H. G. SCHURECHT.

PATENTS

Graphite articles and method of making same. SILAS C. LINBARGER. U. S. 1,339,266, May 4, 1920. A refractory body containing graphite particles coated with a thin oxidation preventing film.

Refractory cement. STAFFORD A. MCMINN. U. S. 1,340,510, May 25, 1920. A cement composition containing not less than 33 per cent and not more than 50 per cent of powdered glass, together with fireclay.

Process of separating and extracting zirconium oxide (zirconia) from ores and minerals. JOHN GORDON. U. S. 1,340,888, May 25, 1920. The step in process of producing zirconia which consists in fusing minerals containing zirconium with a mixture of chloride and an oxide.

Process of separating magnesium from dolomite. ARDON M. MITCHELL. U. S. 1,340,905, May 25, 1920. The treatment of dolomite consisting in pulverizing the dolomite and mixing with it an alkaline hydroxide that does not react to form a compound with the calcium element.

Method of constructing one-piece fire-brick arch. WILLIAM A. A. SCHAFER. U. S. 1,341,077, May 25, 1920. The method consists in arranging a bar or pipe through a boiler setting, anchoring the opposite ends of the bar or pipe in the walls of the boiler setting, then anchoring one end of a metallic sheet or plate in one of the walls of the boiler setting, supporting the opposite end of the sheet or plate upon the bar or pipe and then installing a mass of plastic fire-brick material upon said metallic sheet in the form of the desired arch.

Refractory arch construction. ALFRED H. WILLETT. U. S. 1,342,931, June 8, 1920. An arch construction for fire boxes comprising in combination, an arch tube, a refractory arch carried thereon, and an arch elevating brick, the brick having a tube engaging surface on one face and an arch-supporting surface and an arch abutment on the opposite face. C. M. SAEGER.

Terra Cotta

The influence of grog in admixture with clay. W. C. HANDCOCK. *Pottery Gaz.*, 45, 769-770 (1920).—Water of plasticity, shrinkage and tensile strength tests were made on neat clay and 80 clay mixed with 20 grog. The results with neat clay showed 18.5 per cent water, 5.4 per cent air shrinkage, 8.2 per cent fire shrinkage, 120 lbs. per square inch tensile strength for the air dried clay and 980 lbs. per square inch for the fired clay. With the 80 clay 20 grog mixtures the water of plasticity was 16.6 per cent, air shrinkage 3.8 per cent, fire shrinkage 5.0 per cent, tensile strength of air dried body 60 lbs. per square inch and tensile strength of fired body 400 lbs. per sq. inch. H. G. SCHURECHT.

Enamels

PATENTS

Method for cooling enamel. STEFAN WEISTER. U. S. 1,340,353, May 18, 1920. A method of comminuting enamel to retain its physical elasticity and also its color and to eliminate separate drying, consisting of heating enamel to form a molten mass and then discharging the molten mass in a stream and subjecting the stream to a jet of air moving with sufficient rapidity to separate the molten mass into small particles and blow the particles a sufficient distance to cool the same to such an extent that they will not adhere together. C. M. SAEGER.

Brick and Tile

Vertical fiber vitrified brick paving. C. R. MANDIGO. *Clayworker*, 73, 700-705 (1920).—In making paving brick with an auger machine, the laminations are usually present parallel to the axis of the column. Many brick are cut so that the laminations are parallel to the pavement after they are laid, in which position they are not very resistant to traffic. C. E. Fuller developed

a brick in which the laminations are perpendicular to the pavement in which position the brick are more resistant to wear. In making these brick the column is cut across the $4\frac{1}{2}$ inch face. In firing there was a tendency for the ends to laminate. This defect was overcome by increasing the length of the die to $13\frac{1}{2}$ inches and cutting $2\frac{1}{2}$ inches from each side of the column before it went to the cutter. These brick are laid on their $4\frac{1}{2}$ inch. side and are made in $2\frac{1}{2}$ inch, 3 inch and 4 inch depths. These brick were adopted as standard by the Western Paving Brick Manuf. Assoc. in 1912 and recently by the National Paving Brick Manuf. Assoc. H. G. SCHURECHT.

PATENTS

Mold for bricks and blocks. STOYAN V. TSANOFF. U. S. 1,338,468, April 27, 1920. A frame of three sides having guide flanges adapted to cooperate with another similar frame to form the fourth side of the mold.

Apparatus for making bricks. HENRY W. B. GRAHAM. U. S. 1,341,798, June 1, 1920. This machine is so designed as to pass a mold to be filled with brick mixture to be pressed and then discharged from the molds, which are used continuously. C. M. SAEGER.

Abrasives

Method of making abrasive structures. CHARLES W. THOMAS. U. S. 1,338,598, April 27, 1920. The method consists in mixing abrasive grains with a temporary binder, and a permanent binder consisting exclusively of preshrunk vitreous material; firing the object at a temperature sufficient to cause the permanent binder to flow, and cooling the object. C. M. SAEGER

Cement and Lime

Lime—its properties and uses. Cir. Bur. Standards, No. 30, 2nd edition. —This circular is intended to give general information as to what lime is, how it is made, and what it is used for. Lime is made by heating limestone under certain conditions. This lime, when treated with water, hydrates or slakes. If water is used in great excess, a paste results; but if the amount is properly regulated, the hydration yields a dry powder, which is called hydrated lime. Since natural limestones contain more or less magnesia, iron, silica, etc., the quality of the lime will depend to some extent upon the nature and amount of these foreign materials. It will also depend upon the way in which the stone is burned. As a material for building construction, hydrated lime is better adapted than quicklime because it eliminates labor usually required to do the slaking. It is used very largely as a brick mortar, as an ingredient in concrete and in the scratch and brown coats of plaster. A particular grade of hydrated lime, noted for its plasticity, is sold as finishing lime and is used for the white coat of plaster. Limestone, quicklime, and hydrated lime are used to a large extent as chemical reagents in the manufac-

ture of other materials. In some of these industries the quality of the lime is of minor importance. In others, the use of only one of the three forms of lime is satisfactory, and the quantity and kind of impurity which the lime may contain is definitely specified. Eighteen of the most important chemical industries that use lime are enumerated. Brief descriptions of these industries are given, showing why and how they use lime, and the quality of lime which they require. A list of the tests of lime which are usually made includes chemical analysis, rate of hydration, plasticity, sand carrying capacity, time of set, compressive strength, proportion of waste, and fineness.

E. M. HARRIS.

PATENTS

Method of manufacturing simultaneously hydraulic cement and alkali from alkaliferous mineral substances and lime. ERNST WALDEMAR JUNGER. U. S. 1,338,021, April 27, 1920. The method consists in heating a mixture of the substances by means of fuel to a temperature at which the carbonic acid is driven off, then completing the burning by means of electrically generated heat at a temperature at which the alkali is driven off and substantially without access of air, and separately collecting the alkali and the residue.

Non-porous cement. FRANCES DAVID MULLIGAN. U. S. 1,338,033, April 27, 1920. A compound for water-proofing and strengthening cement comprising a mixture of slaked lime and raw linseed oil in the proportion of 20 ozs., by weight, of lime to 3 ozs., by weight, of oil which mixture is added to the cement.

Cement. DAVID W. ADAMSON. U. S. 1,338,117, April 27, 1920. A cement comprising calcined and comminuted gypsum and calcined alunite ores.

Combined cement. KARL L. TORNØ BERKELEY. U. S. 1,342,360, June 1, 1920. A cement comprising portland cement and dehydrated calcium sulphate and potassium sulphate.

C. M. SAEGER.

ACTIVITIES OF THE SOCIETY

New Members Received During June

- Bonner, James M., Jr., Robinson. Ill., Assistant Manager, Zwermann Company.
- Caruthers, Raymond G., Blandburg, Pa., Assistant to Superintendent, Harbison-Walker Refractories Company, Production Department.
- Dalton, Richard F., Long Island City, N. Y., President, New York Architectural Terra Cotta Company.
- Geer, Walter, Jr., Long Island City, N. Y., Vice-president, New York Architectural Terra Cotta Company.
- Hawke, C. E., Niagara Falls, N. Y., Sales Manager, Refractory Department, The Carborundum Company.
- Hays, George H., Cleveland, Ohio, Assistant Manager, The Vitreous Enameling Company.
- Kennedy, John H., 114 Hubbel St., Canandaigua, N. Y., Assistant Superintendent, Lisk Manufacturing Company.
- Martin, Victor L., Washington Ave., Charleroi, Pa., Macbeth-Evans Glass Company.
- Wry, Thomas A., Lynn, Mass., General Electric Company.

Foreign

- Gunn, James, 59 King Edward Ave., Toronto, Canada, Chemist, Canadian General Electric Company.

Important Actions of the Board of Trustees

July 13.—It was voted to authorize the Treasurer to invest \$3,000 in the next issue of U. S. Treasury Certificates.

July 13.—Mr. S. C. Linbarger, of the Carborundum Company, Niagara Falls, N. Y., was appointed chairman of the Committee on Sections and Divisions.

JOURNAL OF THE AMERICAN CERAMIC SOCIETY

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EDITORIAL

TEN WAYS TO KILL AN ASSOCIATION

The following interesting bit of satire, entitled "Ten Ways to Kill an Association," is reproduced from the *Builders' Bulletin* of Wisconsin. It is commended to the consideration of the members of the American Ceramic Society. The ten ways are as follows:

1. Don't come to the meetings.
2. But if you do come, come late.
3. If the weather doesn't suit you, don't think of coming.
4. If you do attend a meeting, find fault with the work of the officers and other members.
5. Never accept an office, as it is easier to criticize than to do things.
6. Nevertheless, get sore if you are not appointed on a committee; but if you are, do not attend the committee meetings.
7. If asked by the chairman to give your opinion regarding some important matter, tell him you have nothing to say. After the meeting tell every one how things ought to be done.
8. Do nothing more than is absolutely necessary, but when other members roll up their sleeves and willingly, unselfishly use their ability to help matters along, howl that the association is run by a clique.
9. Hold back your dues as long as possible, or don't pay at all.
10. Don't bother about getting new members. "Let George do it."

THE FUNCTION OF AN EDITORIAL

Opinion as to what is the proper function of an editorial probably varies with every reader. A few people hold that it is to disseminate information. Some believe that the purpose is to express the opinion of the majority of the subscribers to the publication in which the editorial appears; others that the editorial is intended to influence the readers to think as the author of the editorial thinks. Still others look upon the editorial column of their favorite journal as a place in which they can obtain their opinions and ideas ready-made without undergoing the mental effort of forming opinions for themselves.

Our own particular idea of the function of an editorial is that it is intended solely to make people think. From this view point it does not matter whether the views expressed in an editorial agree with those of the majority of the readers; it is of no importance whether the editorial contains information of value or not; and it is even immaterial whether the opinions and facts given in an editorial are correct or wrong. If the editorial acts as a spur to the intellect of the readers and makes them think, it has performed its function. The editorials published in this volume of the JOURNAL have been written for the purpose of stimulating thought on questions of importance to the Society *stimulating thought on questions of importance to the Society and the ceramic industries*, and the opinions expressed therein are in no sense to be taken as expressing the views of the Society on the subjects discussed.

ORIGINAL PAPERS AND DISCUSSIONS

THE CONTINUOUS TUNNEL KILN¹

BY CARL B. HARROP

It is an indisputable fact that the ceramic industry has been for many years and is still wasting more fuel than any other single industry. It is true that there have been sporadic attempts to bring into use more economical firing equipment and methods, but the great majority of manufacturers are still using kilns and methods of the same general character as were used many years ago.

The metallurgical industries and particularly the steel industry have given much consideration to this problem of fuel economy and have developed various kinds of regenerators and recuperators, which together with a minimizing of furnace radiation by the use of heat insulating materials, have resulted in not only a large saving to themselves but also a conservation of our natural fuel resources.

The clayworking industry is one of the largest in the country. Of all the steps in the manufacture of clay wares, including winning the raw materials, preparing the clay, forming the ware, drying the ware and firing the ware, the last named (except possibly in some very unusual cases) involves the largest cost of any single step. Furthermore, the principal cost factor in this step is the fuel, so it seems only reasonable that if we would lower the cost of production, the firing operation offers the best opportunity.

In the ordinary periodic kiln, the principal heat losses occur (a) through radiation from the surface of the kiln, (b) in the flue gases and (c) in the ware and kiln structure at the end of the firing period.

¹ Received February 27, 1920.

In many instances the last named loss is reduced to some extent by drawing air through the cooling kiln and using this heated air for drying the ware. Numerous attempts have been made in various ways to reduce the first two losses, but no methods have yet been generally adopted to greatly reduce them.

There is evident a very sincere and widespread interest in the recent rapid development of the car tunnel type of continuous kiln. There are several arguments in its favor, namely:

(a) *Uniformity of firing conditions.* In firing periodic kilns, the time-temperature curve will depend upon the fireman, the condition of the kiln, the setting in the kiln, the fuel, the weather and perhaps some other influences. In the tunnel kiln, it is necessary only to hold a certain fixed temperature, while the rate at which the ware is heated is controlled mechanically, and is dependent upon the rate at which the cars are charged.

(b) *Economy of fuel.* The combustion gases can be cooled to practically any degree (dependent upon the length of the kiln) before being discharged into the atmosphere. The fired ware, moving slowly toward the discharge end, gives up its heat to incoming secondary air for combustion and can be cooled to practically any temperature (again dependent upon kiln length). A saving in fuel of from 65 per cent to 75 per cent over periodic kiln operation can be figured on.

(c) *Economy of labor.* All placing of ware is done at one general location, as is also the unloading of the cars. The firing of all fuel is centralized. Cleanliness and order are far easier than with other types of kilns.

(d) *Construction cost lower than for moving-fire-zone continuous kilns of equal capacity.* The heaviest construction and greatest heat insulation is provided at the high temperature zone—less insulation and lighter construction towards the ends. Every feature and part of the structure is in use at all times. In the chamber continuous kiln, for instance, all chambers must be equipped with full flue systems and other equipment, which are not fully made use of during more than half the time, and, furthermore, all parts of this kiln must be heavily constructed and well insulated.

(e) *Lower cost of maintenance.* Expansion and contraction,

due to the periodic heating and cooling of periodic kilns as well as continuous kilns with moving fire zone, results in considerable damage to the masonry. In the continuous tunnel kiln the structure expands when being brought up to heat and contraction takes place only when it becomes necessary to close down the kiln.

In periodic kiln firing a large mass of ware is heated by furnaces located around the outside of the mass. In order to reduce the firing time as much as possible, the temperatures carried in the furnaces are necessarily exceedingly high. This results in severe punishment to the furnace linings and bags. In the case of the tunnel kilns, a relatively small mass of ware gradually approaches the high fire zone. It is possible to have far greater furnace power per unit mass of ware, with the result that it is not necessary to have a furnace temperature, which is as much in excess of the desired ware temperature as is the case with periodic kilns. The advantage is evident.

The purpose of any kiln is to generate heat from the fuel provided and to enable an efficient and prompt transfer of this heat to the ware being fired. Also, it is equally important that all the ware being fired shall be subjected to practically the same degree of heat, so as to secure uniformity of the fired product. There is still a third requirement, which cannot be given too much consideration, namely, capacity of the kiln. Several of the tunnel kilns now being advocated are able to fire ware uniformly, if the ware passes through them slowly; but when the rate of passage of ware is increased, and particularly if the ware is massive, uniformity of quality is greatly reduced.

For firing of certain products, such as sanitary ware set open, terra cotta, and so forth, the muffle tunnel kiln, without question, most nearly meets the requirements. However, for all sagged wares and for most crude structural wares, it would seem that the open or direct-fired tunnel kiln is the most practical. It is essential that this latter kiln (which embodies the horizontal draft principle of firing) shall be properly designed; the heat applied at the proper elevation and in the proper way, and that the designer have a thorough knowledge of combustion and its control in connection with the ware being fired in each particular instance. Under

the above conditions, there is hardly a doubt that, for a given degree of uniformity of quality, the direct-fired kiln is capable of a greater capacity than the muffle type. However, regardless of comparisons between the two types, the important point which should be thoroughly investigated by all prospective builders of tunnel kilns, is whether or not, with an assured *quality* of product, the daily *capacity* will warrant the cost of the installation.

The tunnel kiln, properly designed and carefully built, is undoubtedly destined to become a thing of great economic importance to the clay-working industry of the country and is sure to supersede the antiquated methods still being clung to by most manufacturers.

OHIO STATE UNIVERSITY
COLUMBUS, OHIO

NOTICE—*Discussion of this paper will be published later as part of the Discussion on Tunnel Kilns.*

THE TUNNEL KILN APPLIED TO CERAMICS¹

BY SAMUEL TROOD

There are three principal items to consider in firing tunnel kilns: (1) Heat generation, (2) heat distribution, (3) heat absorption.

Heat generation requires a proper combustible, proper oxidizing agent, proper temperature and in the proper proportion, and a proper mixture of the above. There are two factors in the generation of heat, which are very often misunderstood, *viz.*, the quantity of heat and the intensity of heat.

It is a well known fact that some operations require a higher temperature than others, but this must not be confused with the fact that some operations require a greater amount of heat at certain temperatures. (Example—water.)

The intensity of the heat determines the time element of an operation. It is a matter of laboratory record that heat conductivity, radiation, absorption and convection are proportional to the difference of temperature of the heated substances and the heating medium, the constant varying with the different substances.

Heat distribution and heat absorption are very closely related and cannot be considered independently. In firing porcelain, there are four (4) distinct danger zones:

1. The ware is heated up until it reaches the boiling point of water.

2. When the contained water of crystallization begins to break up—this zone to consider safely is between 750° and 900° F.

3. Where the less refractory ingredients begin to fuse and the whole mass becomes more or less soft. The firing between these stages can be quite intensive

4. After the firing (soaking zone) cooling begins, and with some material rapid cooling is permissible to the temperature of a dark red. After that a gradual and slow cooling is necessary.

¹ Received February 27, 1920.

The above brief summary of the danger zones shows that the very exacting requirement in firing porcelain is obviously difficult to observe, when applying to the beehive kiln. The heating of the whole mass of ware and saggars cannot be easily accelerated or retarded rapidly.

This brings us to an arrangement where a proper cycle may be obtained by localizing the intensity of heat in certain portions of the kiln and have the section so proportioned that the material being moved at constant speed is for a longer time under the influence of the heat at the point in question.

The main factors controlling heat distribution and heat absorption in a tunnel kiln are: (a) Size of the car, (b) amount of ware on the car, (c) size of passages. Items *a* and *b* are usually predetermined by the output contemplated. It is really the proportion of the passages and the combustion chamber that determines the performance of the kiln and its efficiency. Assuming that the kiln is proportionally designed to take care of the output, the question of proper firing becomes of the most importance.

There is no set rule for firing of all fuel, except the fundamental fact that sufficient space must be provided for combustible gases and proper provision made for the mixture of those gases with the oxidizing agent. Independent of the original fuel, it is the gases that produce combustion. In coal firing the gases are obtained by a partial distillation. In oil firing, the gases are either vapors or true gases of the oil, and the closer the state of the oil approaches the state of perfect gas the more efficient is the combustion. That is why oil-firing system that gassify the oil before combustion obtain higher efficiencies and higher temperatures. Gaseous combustibles are not only conveniently mixed in the proper proportion with air, but ignite immediately on coming in contact with the proper temperature without going through any intermediate stages.

The size of the combustion chamber is determined by the kind of fuel used. When solid fuel is used, large volumes of gases are distilled off and a large excess of air is usually employed. All this calls for a large combustion chamber. When liquid fuel is used, the combustion chamber may be somewhat less than with

solid fuel, but just big enough to give sufficient travel for the atomized or vaporized oil to gasify. When gaseous fuel or liquid fuel in gaseous state is used, the smallest combustion chamber can be employed.

It is interesting to note that with the truly gassified oil the size of the combustion chamber may be much smaller than if gaseous fuel is used. This is explained by the higher heat contents per cubic foot of gassified oil as compared with the natural, city, or producer gas.

When a concentrated gaseous fuel is used and the air is so controllable that an amount as close to the theoretical requirement as possible is used, the calculation of the combustion chamber to correspond with the proper distribution of heat is possible with a fair degree of accuracy. In firing ceramics, where the final result is obtained by a close following of the proper time temperature cycle, especially through the danger zones enumerated above, proper distribution of heat is vital. As distribution and generation of heat are closely interlocked, proper combustion is really the basic requirement for successful operation. The continuous kiln not only gives a proper distribution but allows flexibility of design of the combustion chamber.

The muffle type of kiln seems to be as yet the most efficient furnace for firing of porcelain as the passages for the production of combustion can be lengthened, widened, deflected or arranged in any way to correspond with the quantity and intensity of the heat required at any particular point. The proper length of the kiln is generally a matter of considerable discussion. In our opinion it is a matter of simple calculation and depends solely on the output contemplated and the time temperature cycle employed.

For the single tunnel kiln, if you multiply the length of the car in feet by the number of cars to pass through the kiln per day by the time in hours of complete cycle of firing, and divide by 24, you will get the length of the kiln. If this item is not divisible by the number of cars add to this enough to make an even amount of cars. If this is a double compensating kiln, half of this length is sufficient.

As compared with a periodical beehive kiln, the continuous kiln has the following advantages:

1. The losses due to the defective placing, defective distribution of heat and inadequate control of the heat, are eliminated.
2. The ware is handled with maximum convenience as the placing is done outside of the kiln and only shoulder high.
3. The saggars are done away with. This not only means a saving of fuel, but a considerable saving in cost of saggars.
4. The losses due to intermittent heating and cooling of the kiln are eliminated.
5. Smaller up-keep expense.
6. The heat stored in the ware is utilized for preheating the incoming ware and the air for combustion.
7. The firing cycle is considerably shorter.

The double compensating kiln has many advantages over the single tunnel kiln, *viz.*:

1. It requires a shorter floor space for the same output. This gives a structure which is better proportioned for placing in an ordinary building.
2. Radiation losses are much less and therefore it is more economical. The middle wall of a double kiln takes the place of two outer walls thus saving one-half of the side surface radiation.
3. A better control of temperature and quantity of heat is obtained. As the heat is delivered to the ware by convection of gases and not by radiation from the walls, it is obvious that the distance that this gas will have to travel is the limiting feature in the control since these gases can be sent only a short distance without excessive loss.
4. Less initial expense for building and equipment. A double kiln requires half as much side plating and buckstays, wall insulation and usually less brick as the center wall is thinner than two side walls. The foundation is shorter and wider; this resulting in a better and stronger structure. Less attention has to be paid to expansion joints and piping is considerably shortened.

5. Less maintenance expense. The shorter the kiln, the fewer are the number of expansion cracks, which are inevitable in spite of all provisions for expansion joints.

With a properly designed kiln (that is, with a commercially scientific control of heat generation and distribution), firing ceases to be the problem of an expert. The cycle of firing once determined can be strictly adhered to, and anyone with enough intelligence to turn the valve in the right direction can be entrusted with the operation. It is not too optimistic to state that in the future, and let us hope in the near future, ceramics as an industry will be put on the same basis as any other manufacturing enterprise and the black magic of firing eliminated.

UNITED STATES SHERARDIZING COMPANY
PITTSBURGH, PA.

NOTICE—*Discussion of this paper will be published later as part of the Discussion of Tunnel Kilns.*

THE DRESSLER TUNNEL KILN FOR FIRING SANITARY WARE¹

BY GEORGE BRAIN

Owing to the erratic results that were being obtained at the plant of the Universal Sanitary Manufacturing Company at New Castle, Pa., during the year 1915, particularly with their glaze firing, the management decided to take what might be called a very grave departure from the methods then in use for the production of the finishing gloss on sanitary ware and to build a continuously operated tunnel kiln, of the muffle type, known as the Dressler tunnel kiln, which incidentally was the first in America, and the first in the world for firing sanitary ware.

It seemed foolish to them to continue to place ware in saggers, and gradually bring the heat to the goods, and then cool, wasting time and enormous quantities of fuel. They were convinced that the right method was to maintain the temperature desired near the middle of the tunnel, bring their goods up to the heat, and then past to the cooling zone, using the heat from the goods, to help conserve the precious fuel, which they had been wasting for years in their intermittent kilns.

The potters would have argued, "we know we are getting fairly good results by our present methods. Well, anyway, as good as may be obtained with our present equipment which we know something about while we do not know what the results will be if we take such a step as putting in a continuous kiln as part of our equipment, which is all theory and remains to be proven."

I was not connected with the company when the decision was made. It is just possible, however, that had I been consulted as a potter, I would probably have advised against such a step. Therefore, I am not speaking as one taking pride in having made the proposition, but as an enthusiast after the event.

¹ Received February 27, 1920.

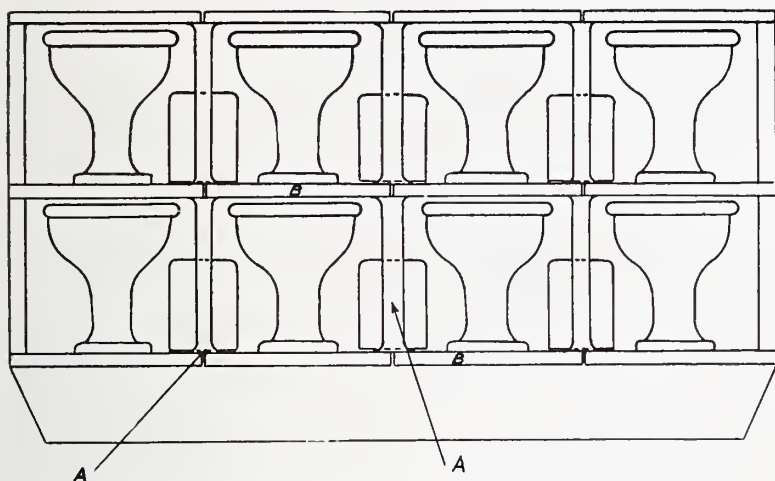


FIG. 1.—Side view of loaded truck. *B, B* are fire-clay slabs. *A, A* are supports on outside of slabs *B* used for supporting upper deck. Behind these supports and between the bowls small articles can be fired as described in the paper. It will readily be seen that by enclosing the bowls in saggars the space would be divided and thus ruined for use for extra pieces. The sketch shows one side of the truck holding 8 closet bowls and 6 jars, or a total for the truck of 16 closet bowls and 12 jars. When tanks are placed the total number of tanks that can be fired vary from 10 to 12 according to the size of the tanks.

The kiln is approximately 250 feet long and holds 44 trucks, each measuring 5 feet 8 inches long and 3 feet 6 inches wide. Each truck is capable of holding 18 large pieces of sanitary ware (8 tanks, 10 closet bowls). At 22 trucks per day (7 days per week) the production would be 396 pieces of sanitary ware per day, or figuring on a six-day basis for shop production, 462 pieces per day from the shops. We have never been able to produce this amount. Our total production per day from the clay shop has never exceeded 360, so that the tunnel kiln has never been pushed to its capacity. Incidentally we are hoping to make the 450 mark this summer when we get our new casting shop in operation. The distance from the entrance to the maximum temperature zone, speaking in trucks, is 28 and from there on to the end of the kiln is 16 trucks. Based on a maximum production

of 44 trucks per day, or one per hour, the time occupied by the ware from placing in kiln to time of coming out is only 44 hours. Adding to this the extra six hours given for cooling, in an ante-chamber provided on our return truck, the time occupied is 50 hours, from placing to packing shed. Compared with the intermittent kilns there is a saving of the difference between six days (144 hours) and 50 hours, which equals 94 hours, which means that the time occupied by the process of glazing is cut down by about 60 per cent. Compare the amount of fuel used in each case.

An intermittent glost kiln will use about 250,000 cubic feet of gas per kiln, or if coal is used, about 15-16 tons. The Dressler kiln uses 50,000 cubic feet of gas per day or intermittent kiln equivalent. If using coal in a gas producer 3 tons per day or intermittent kiln equivalent will suffice—an actual saving of four-fifths, or 80 per cent, of the fuel, which in itself is not to be taken lightly during this period of high cost of living.

It is interesting here to note that when on a few occasions we used saggars on several trucks our production per truck was cut down from 18 to 10, or 44 per cent. In addition to this, when using saggars we were not able to fire smaller articles without providing extra space for them. The reason for this you will readily see. On each side of the truck (lower deck) we fire 4 closets, or 8 in all, which leaves 6 spaces to be filled. All kinds of articles fairly large in size, can be fired in these spaces, such as paper boxes, water coolers, etc., equal to a production of about 850 pieces per week.

On one occasion we took an order for a certain type of white jar for which we had to provide special saggars in the bisque. Had we continued to do this our profit on the jars would have been small. Instead we raised our heat in the tunnel kiln to cone 9, hardened our glaze a little and dipped the jars green, firing them but once through the tunnel kiln. We saved considerably on this, because in raising our heat from cone 7 to 9 we only used an extra 5000 cubic feet of natural gas per day, costing \$1.75—about one and one-half cents per jar.

These savings are worth while and were not thought of when the kiln was first installed. Firing without saggars has tre-

mendous advantages. Each piece of ware can be seen and inspected from the time it is placed until it enters the kiln. Our kiln operators are thus able to check any slips that our kiln placers may have made.

The saving in equipment and labor is also enormous. (1) Our men place all our ware during an 8-hour day, while 2 men working day (12 hours) and 2 men at night (12 hours) put the trucks in the kiln and unload same as they come out. (2) As all our slabs and supports are cast they stand up well. We use an average of two large slabs per day, and several small supports. You will readily see that the displacements of ware for firing these is very small indeed. This would not be the case with saggars.

Based on a production of 70 green saggars per day (35 rings and 35 bottoms) there would be a displacement of 35 pieces of ware, which, based on a profit of $12\frac{1}{2}$ per cent, would mean that the company would be the loser of \$12,000 each year, irrespective of what it cost to make the saggars and the space occupied by the saggars and sagger room. Wadding is entirely eliminated. This effects a direct saving of thousands of dollars per year, which any manufacturer will appreciate.

Six men, including kiln placers, operate our Dressler kiln, working a total number of 64 hours per day, or, based on a 7-day week or a 7 intermittent 16 feet 6 inches kiln equivalent, 448 hours per week.

Let us see how many men it takes to produce 7 intermittent kilns per week. Seven 16 feet 6 inch kilns will average 50 bungs, or 350 bungs per week. Each union kiln placer sets 7 bungs per day (8-hour day) or it takes an equivalent of 50 times 8 hours per week equals 400 hours for kiln placing. Drawing the same kilns finds work for 10 men each time a kiln is drawn, of 5 hours each kiln or 50 hours per kiln for whole gang, or 350 hours per week. It is fairly reasonable to say that 1 fireman and 4 helpers will fire 7 kilns per week. One fireman 8 hours per day for 6 days equals 48 hours per week. Four helpers 12 hours equals 48 hours per day or 7 days equals 336 hours per week. It is safe to assume that it will take an extra laborer for punching and cleaning up 8 hours per day for 6 days or 48 hours per week.

Unloading 105 tons of coal 10 hours per week. Just these alone will give the huge total of 1192 hours per week for the same product as one tunnel.

In using the number of hours per day as a comparison, I believe I am able to show you without giving you actual dollars and cents exactly what we save on labor alone. Let us compare—448 hours per week for Dressler and 1192 hours per week for seven 16½ ft. kilns, a saving of 644 hours per week or in percentage about 55 per cent.

Had it been necessary for us to use saggers in our Dressler kiln it will be readily seen that our labor saving would have been very small, besides which we would have cut down the production to an enormous extent. Had saggers been used one bottom and one ring would be used per piece of sanitary ware. Our kiln placers instead of handling 400 pieces of ware or thereabouts would have to handle 400 pieces plus 800 saggers with necessary wadding. That of course is assuming for sake of comparison that the same number of pieces could be fired with saggers; as a matter of fact the actual production would be cut in half and even at that would give the two kiln placers more work than they could handle. It is very easy to see that our kiln placers would be multiplied by 3, or instead of 2 we could need 6, and at least 4 extra men would be needed for the drawing irrespective of the extra cleaning up that would be necessary. The labor saving appeals very much to me indeed, especially with regard to kiln placers. Where could we possibly get 4 extra kiln placers, not to speak of kiln drawers? As matters stand in the skilled labor world, it is next to impossible. They would, however, be necessary, if we used saggers, which certainly would be the case if it were not for the fact that our kiln is of the muffle type. It is not that we save money on the labor so much as the fact that we are able to operate with so few laborers.

In regard to quality it may be said that we are able to steadily produce goods of first-class quality, with none of the glost defects so prone to crop up in sagged kilns of any description which are direct fired.

It will be interesting here to note what our repairs have cost us during 4 years of operation. Three years ago we decided to

repair the arch in the heat zone which had sunk about 3 inches owing to low-grade fire brick having been used. We made a number of arch bricks ourselves from what we considered after a series of tests would give us good results. Six hundred were used in all and they are in the kiln to-day in first-class shape. We have also used 20 to 25 sections of combustion chambers during four years, not a terrible expenditure by any means, either in labor or materials.

Since the first few trial trips in the fall of 1915, when we shut down the kiln to make any improvements the operating had suggested to us, we have had one run of fifteen months and two of twelve months each. Twelve months ago we voluntarily shut down when the sanitary business was at its lowest ebb. Had this not been the case I firmly believe we would have run for a full two years—not at all a bad record for a kiln operating at cone 7 and part of the time at cone 9.

UNIVERSAL SANITARY MANUFACTURING CO.
NEW CASTLE, PA.

NOTICE—*Discussion of this paper will be published later as part of the Discussion of Tunnel Kilns.*

DISCUSSION OF TUNNEL KILNS*

MR. GILL: On account of the heavy nature of the ware we put through the kiln we have to keep the hot zone at 2400 to 2500 degrees F, about 2400 degrees on the average, and the ware is about three days in the hot zone. We run a little more slowly than some of the gentlemen, about 2 feet an hour, on account of the weight of the ware. The cars moving through the kiln are covered with a refractory material that we manufacture ourselves. This is in the shape of a large block about 8 inches thick placed on top of the cars and ventilated with holes so as to allow the circulation of the heat all through the ware that is on top. I am sorry we did not have some one to explain the working of these kilns before we talk about the results, about the way the kilns are cooled below and the scientific manner in which the drafts of the kiln are taken care of. It was remarkable to me that we could have a heat of 2400 degrees in the kiln and a downpour of heat into the space below the cars not hot enough to light a piece of paper.

MR. J. B. SHAW: I do not know whether the gentlemen stated or not, but I have heard that they have eliminated saggers and seals.

MR. C. DRESSLER: I shall be very pleased to answer any points on which you may wish information. First, let me say that I much object to hearing the Dressler kiln so often referred to as a muffle kiln. This description appears to me an inadequate one. The most important point is overlooked when you talk about it as a "muffle kiln." A muffle, we know, consists of one fire-clay box within another, the flames passing between the two shells, and, in the Dressler kiln, we are not doing that at all. We did not adopt the internal combustion chamber primarily because we wanted to keep the flames from the goods. Our main purpose was the control of the flame—to burn the fuel

* Annual Meeting, February 25, 1920.

completely, and without excess of air, and, therefore, as economically, efficiently or scientifically as possible. Our second, a not less important purpose, was to impart the heat thus produced to the goods with uniformity throughout. You know that it is quite impossible to burn gases efficiently if you let them loose among the goods, and that truth applies to all forms of fuel. No mean exists by which you can regulate the mixture of air and fuel in an open kiln, whether periodic or continuous. Seger tells us that after numerous investigations, in the continuous circular or ring kiln, he never found less than ten times as much air passing through it as was needed for combustion. Well, 12 cubic feet of air weigh one pound. The weight of this excess of air in an open kiln calls for a fuel expenditure of not less than 55 to 60 per cent over and above that which is really needed if the fuel is accurately burnt as in the Dressler kiln. You realize what that means on your fuel bill. The analysis of our burnt gases shows as high as 19 per cent of CO_2 . This is practically the maximum possible.

I must again point out the benefit of control. It is the whole secret of progress. By its means, we can apply the heat just where we want it. We can lengthen or shorten the heat zone at will. In fact, we decide what the heat curve shall be and are masters of the heat, not mastered by it.

Now, we do something more than this. By means of our chambers, we are able to use only hot air of recuperation—not cold air which is used in so many cases. This is a great saving. Further, we are able to recover nearly all of the remaining heat from the fired goods, in the form of hot air. The fuel value of this is not less than 40 per cent of the calories put into the kiln. Thus, where it has been usual to fire goods in a periodic kiln with twenty tons of coal we are able to do the same work with, say, five tons. Only three of the five are used for actual firing, and we return two tons' worth as hot air. That will be something acceptable to those who have to dry their goods. This is a distinctive feature of the Dressler kiln.

To answer Professor Shaw's question, it is by the same means of control that we keep the heat from affecting the metal parts of the truck. We were able and very glad to give up the use of

sand seals, because the convection currents which take place at the level of the benches of the kiln are so intense that they practically keep the heated air from penetrating below. These convection currents exist for the whole length of the heating zone. I do not mean to say that we have not got radiation at certain points. When we come to the hottest point radiation overtakes convection and here it helps us, because by that time the goods are thoroughly permeated through and through with heat. You know the difference between radiation and convection as well as I do. You know that you can toast a piece of bread quite brown in a very short time if you hold it in front of a hot radiating fire, while the other side will remain white and cold. On the other hand, if you interpose ever so thin a screen, you will never make the toast. It is equally evident that the screen between the inner chamber and the goods prevents the radiation which will produce the undesirable inequality of heat distribution. That is the secret of our uniformity of heat throughout the goods. You have heard Mr. Gill tell you about it in actual production and there is therefore no use in my going into further explanations.

With regard to any heat which travels down through the body of the car by conduction, this we remove by means of cooling pipes, drawing it off in the form of hot air or, in some cases, hot water. In the former instance, this heat, small as it is, is added to that which the manufacturer can have for his drying purposes. In this way, the metal parts are kept so cool that, as you have heard, paper will not char when fixed to the under part of the cars, even after an exposure of five days in the kiln.

Mr. Sproat has spoken of the trouble he has had with tar and so forth, which he has now, however, overcome. This is a producer trouble. Where so many different types of fuel are used a trial period is necessarily first experienced in the gasification. With anthracite or coke there is no trouble. Where bituminous coals occur, which lead to more or less caking and clinkering, it is necessary to find out the best way of handling the producer so that a smooth production of gas may take place.

One more thing I would like to say. Some people seem to think that our kiln, having such very thin-walled combustion chambers, must be a very delicate apparatus and one suited only

for delicate ware—not for such products as brick, paving blocks and heavy materials of that sort. You have seen on the screen the glass tank blocks, which we fire. They do not appear very delicate affairs. As regards large outputs and big weights, I may tell you that we have kilns at present firing no less than 300 tons of material in 24 hours, which, in terms of brick, would be equivalent to 100,000 per day, and this production goes on year in and year out, in some cases for three years without a stop. That is my answer to anyone who is afraid that our kiln is not suited for the production of large quantities of common building materials.

MR. E. K. PROODIAN: If you have a breakdown in the muffle how long does it take you to get into the kiln and replace the muffle and heat it up again?

MR. C. DRESSLER: That depends a great deal on the heat of the oven, and so forth, but I think ten days.

MR. ELLSWORTH OGDEN: I would like to call attention to one statement Mr. Dressler made, that he felt it was impossible to get perfect combustion, or impossible to control the combustion anywhere outside of a muffle. Now, as a matter of fact, in this muffle he must control the combustion. If he gets an excess of gas, combustion will take place too far down in the tunnel, and if he gets too much air, his flame will be too short. So he must control his combustion even inside that muffle in order to get the results he wants. Now, then, the advocates of open firing maintain that if your fire boxes, or your furnaces, or combustion chamber, or whatever you call it, are properly designed, you can control the combustion within that chamber just as perfectly as it can be controlled within the interior of any other combustion chamber; and if your combustion is properly controlled then the products of combustion are free from a reducing effect. They contain only the normal products of combustion and whatever sulfur your fuel has, and they are not injurious to the ware any more than those in any other type of indirect fired kiln. It is a question of control of combustion, whether you control it inside of an inner wall or within an ordinary combustion chamber and in the direct-fired kiln it has been possible to control this com-

bustion so that there is an entire absence of flame in the tunnel at all times.

MR. SAMUEL TROOD: To emphasize Mr. Ogden's statement, I may say that to create combustion, a combustible, oxidizing agent, proper temperature and thorough mixture of the above are necessary. Assuming that the combustion chamber is correctly figured, the temperature obtained is such that by increasing or decreasing the oxidizing agent the temperature falls down, thus creating a chemically neutral quality of the flame. Let us call this condition 100 per cent. With the deficiency of air up to 30 per cent, the temperature will gradually fall and still create a smokeless combustion with gases of reducing nature. With a still greater deficiency of air the combustion becomes smoky and uncontrollable. With excess of air up to 30 per cent the temperature will also go down, the flame will be smokeless and the gases of oxidizing nature. With further excess of air the combustion becomes uncontrollable.

It is possible to fire a kiln with direct flame, producing desired results, especially if the combustion chambers are placed outside the kiln and if the supply of combustible and oxidizing agents is under full control. In the Kirk muffle tunnel kiln recently constructed for the Westinghouse Electric and Manufacturing Company, neutral or reducing atmosphere in the combustion chamber was created at will.

MR. A. F. GELLAR: Can a tunnel kiln be operated at cone 18 economically?

MR. J. B. OWENS: Yes sir. In the direct-fired tunnel kiln that we are building we give in one of our movements a six-hour soaking heat. We go up gradually and can go from practically atmospheric condition up to 2500 degrees F or almost as much higher as you desire to go, certainly away beyond cone 18, because we have burned up to 2900 degrees F. At the cooling end of the kiln, the ware cools almost perfectly. Now this was not the case when we were experimenting on tunnel kilns, because the first tunnel kiln we built was only 160 feet long and had only one firing zone. Today we build our kilns 240 feet long, and they are as near perfect as a tunnel kiln can be built, and we can prove

it to any man who has a prejudice or who doubts the proposition. When you can take a direct-fired tunnel kiln and operate on a one-hour movement, six hours' soaking, then you really have a kiln. Every man here knows that clay ware must be burned through and through, that he can not burn the outer surface only and still have a good product, that it must be burned to the center just as well as the outside, and that a soaking heat is absolutely necessary to secure this result. Another thing every one here should understand is that a direct-fired kiln must, of necessity, have a greater capacity than any kilns which have frills and furbelows.

MR. E. C. STOVER: I would just like to ask the cone 18 gentleman where he got his fire brick. Did he get them from Germany?

MR. J. B. OWENS: You can get many of them in America; cone 18 is only 2642 degrees F. We have burned way beyond that and the bricks stood the test.

DR. SAMUEL TROOD: I think they might stand for a short period but not for a year continually.

MR. J. B. OWENS: How much more is the heat in your fire-brick box than the kiln? The old type kiln I refer to. You ran your old type kiln to cone 12; how much hotter is the heat in your fire box than up in your kiln?

DR. SAMUEL TROOD: But they burn out.

MR. J. B. OWENS: Ours will burn out at times, but we have experienced no trouble of that kind except with one kind of brick.

DR. SAMUEL TROOD: How do you control the flame going right into the kiln?

MR. J. B. OWENS: We do not have any flame going into the kiln.

DR. SAMUEL TROOD: You call it products of combustion. I call it flame. How do you control the zones? By zones I mean places in the kiln where the temperature is to be raised or lowered. For example, how do you retard the temperature when the ware begins to reach 750 degrees and up to 900 degrees?

MR. J. B. OWENS: We do not retard to soak. Our heating

zones are large enough to give us the soak as the cars pull through. We never change our heat after the kiln is once full.

DR. SAMUEL TROOD: I appreciate that, but how do you install them in your kiln?

MR. J. B. OWENS: That is done by dampers in the walls of our kiln. We can control that as near perfectly, I believe, as it can be controlled.

THE CHAIR: I hope that within the next year some of our wealthy manufacturers will build one of these 18-cone kilns and give us the results at our next meeting.

MR. R. C. PURDY: One is now being operated at cone 16-17, in which they do reach 18 at times.

MR. STOVER: In Berlin they have a kiln in which cone 18 is produced, but I am asking where in America you can get a brick that will fire ware at cone 18?

MR. F. C. RIDDLE: May I make a statement which I think I can substantiate? Burning cone 19 down is perfectly possible and is being done in the United States in periodic downdraft kilns at least 14 feet in diameter. There are several types of brick that will withstand this temperature; and with the so-called super-refractories, it is possible, if you want to spend the money, to burn cone 26 down if you have fuel that will do it.

MR. E. C. STOVER: Would you mind giving us the address?

MR. F. C. RIDDLE: I know that Hy-Brand brick will stand up at cone 18, and there are several others.

MR. HOWELL: In the past six months I have come in contact with 24 or 25 brands of fire brick made in England, Scotland, Germany and Sweden, and I believe there are a couple of brands from Canada, and with only one exception did we find any of these foreign bricks which were not fused or soft above cone 32. One brand which was called the Snowball fused above cone 32; but outside of that one brand, we did not find anything which would cause any serious competition with the better grade of American refractories.

DR. SAMUEL TROOD: We were talking about continuous kilns. So far as the best intermittent kiln, either downdraft or updraft

kiln is concerned, we do produce these results. I got them myself, but every time I burned down the kiln from the roof to the bottom. There is no question but that we can do it, but we are talking about a continuous kiln where the repair, as Mr. Dressler said, means ten days, and means not only considerable money, but ten days' interruption to production. As a rule, any reputable kiln builder employs carborundum blocks. The Dressler kiln has carborundum blocks and carborundum chambers and they stand.

A MEMBER: How long do you guarantee them to stand?

DR. SAMUEL TROOD: Until a foolish man comes along and puts in a charge of something that will blow them up.

MR. R. J. MONTGOMERY: In burning a tunnel at cone 18 (1500 degrees C-2732 degrees F) to use fire-clay refractories in the hot zone would be to invite trouble. There is too small a factor of safety in the material. The A. S. T. M. standard temperature for testing first quality material is only 1350 degrees and practically all fire brick will show a shrinkage when held at 1350 degrees C for $1\frac{1}{2}$ hours under a load of 25 lbs. per square inch.

A few brands might be found which will stand the load test without linear shrinkage of 2 per cent or more, but holding for months at a temperature of 150 degrees C higher would certainly cause some shrinkage. Also the fire-clay mortars are not as free from shrinkage as the brick. The total shrinkage of mortar and brick could easily cause the wall to sag. Probably complete failure would not occur with a very high grade brick, but undesirable shrinkage would certainly be obtained. Insulation for fuel economy would prevent the use of thin walls so only the inside surface would reach full heat.

The coke oven is a good example of where silica has replaced fire brick when continuous high heats are used. Cone 18 or 20 could be held indefinitely with no softening effect or shrinkage either on the brick or mortar. You still have a reasonable factor of safety and accidental overheating would not cause as much damage as with fire-clay refractories. Coke ovens have given 8 to 10 or more years of service with working temperatures from

1525 degrees C to 1575 degrees C without signs of failure from lack of refractoriness. There is no sagging of the wall and loss of alignment due to shrinkage.

DR. SAMUEL TROOD: I may emphasize that remark about refractories with a very few short words. During the war, being in charge of a metallurgical proposition in California, the question came up where to get refractories, that would stand in an electric open-pit furnace. You gentlemen know how high are the temperatures produced with direct process of ferromanganese. I could not get the refractories and used common brick, yellow brick at \$40 a thousand. I made the walls quite thin, jacketed all around with boiler plate and water-jacketed the furnace. Of course, I paid considerably for that, but ferromanganese at that time was worth \$410 a ton, and that would pay for any expense. That was one way a kiln could be built, by cooling the combustion chamber.

I had so far trespassed upon the time of the convention that I felt that I could not take up any more of it in answering Mr. Ogden. I am therefore glad of the opportunity given me of preparing a written reply. The difference between burning the fuel in a combustion chamber placed inside the oven, as in the Dressler kiln, and of burning it in a fire box placed outside the tunnel, in the case of an open fire tunnel kiln is considerable.

1. Our combustion chamber is controlled at both ends. All the products of combustion burnt in it pass into a flue with a damper to it. The products of combustion in the second case pass into the oven or tunnel, which has doors at each end through which air will enter every time the goods are put in or taken out and the flues therefore are drawing not only on the fire box but on the two openings in the tunnel. The difference in the control is evident.

2. Now with regard to economy, all the heat used in the period of incipient to complete combustion goes into the walls of the chamber. If this is outside instead of inside, all the heat which radiates from this chamber is lost.

3. In the open tunnel the air with which the fuel is burnt in the outside fire box is mostly cold. Therefore, the principle of recuperation is not used at all or only in a small degree. This

means that a large proportion of the fuel is used in heating up cold air.

4. As the burnt gases from this fire box enter the kiln, they encounter and mix with the cooler air, which enters the tunnel ends through the doors every time they are opened. All this air has to be heated up uselessly to the top temperature required.

Thus, though the air and fuel put into the outside fire box may be in the proper proportion, as soon as they enter the kiln, this proportion is entirely upset. It is only necessary to analyze the products of combustion to realize this. As a consequence of using the tunnel itself as a flue, an unavoidable variation of temperature in the kiln occurs every time the doors are opened.

THE CHAIR: We will have to consider that this closes the discussion. If you have anything further, we will ask the gentlemen involved to conduct the discussion by mail. The way this session has developed has been a source of considerable personal satisfaction to me. It was my desire to have this on the program last year, but for certain reasons it was not possible. I hope next year we will be able to continue this along with other sessions of interest to factory men.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

SPECIFICATIONS FOR COMMERCIAL FELDSPAR AND FLINT¹

BY ARTHUR S. WATTS

Specifications Covering the Purchase of Pulverized Feldspar to Be Used in the Manufacture of Whiteware

I. The Sample.—In sampling car-load lots, equal amounts shall be taken from at least five different points in the car, no two samples being taken within five feet of each other.

In sampling from a bin, five separate samples shall be taken from different portions of the bin and not more than two from the same level. The total sample shall be not less than ten pounds. The samples shall be thoroughly mixed on a smooth surface divided in halves, one-half spread evenly over the other half. Repeat this operation five times. The mixed sample shall then be quartered and two quarters not adjoining rejected. The remaining quarters shall be mixed, as described above, five times, quartered as before, and two quarters rejected. The remaining sample shall weigh more than 2.2 pounds (1 kilo) and shall be placed in a tight receptacle, and marked with an identifying number or with the name of the material, car or bin number, and data on which sample was taken.

II. Chemical Composition.—1. Feldspar sold as potash feldspar shall contain not less than 9 per cent K_2O , and not more than 3 per cent Na_2O and not more than 1 per cent $CaMgO$, and the sum of the potash and soda contents shall be not less than 12 per cent.

2. Feldspar sold as soda feldspar shall contain not less than 7 per cent Na_2O , not more than 3 per cent K_2O , and not more than 2 per cent $CaMgO$, and the sum of the potash and soda contents shall not be less than 10 per cent.

3. Feldspar sold as mixed or blended feldspar shall contain not less than 11 per cent total potash and soda content.

¹ Received February 27, 1920.

III. Physical Properties and Tests.—1. **Color.** The feldspar when formed into a standard sized cone and deformed in a closed sagger or muffle shall show a uniform white color and no specks either on the surface or on the interior of the cone when broken.

2a. **Fineness of Grain.** One hundred grams of the sample, after being dried to constant weight at 105° C, shall be tested for fineness of grain according to the process set forth in paragraph 2b and the residues on the various standard sieves shall not exceed the maximum totals as set forth in the following table:

| Standard Sieve Mesh per Linear Inch | Each Sieve Per cent | Residues | Max. Total Per cent |
|--|------------------------|----------|------------------------|
| 65 | 0.25 | | ... |
| 100 | .25 | | 0.50 |
| 150 | 1.75 | | 2.25 |
| 200 | 3.75 | | 6.00 |
| 260 | 5.00 | | 11.00 |
| 325 | 7.00 | | 18.00 |

All percentages are calculated on dry basis.

2b. **Method of Making Fineness of Grain Test.** The 100 grams of dry sample shall be transferred to the sieve and placed over a sieve pan which fits closely enough to prevent loss by slopping. The pan shall contain sufficient water to reach within not less than $\frac{3}{4}$ inch or more than $1\frac{1}{4}$ inches from the pan. The sieve and pan shall be vibrated or shaken in such a manner that the water in the pan is splashed on the screen from below so as to wash the powder about and cause the material that can pass through the sieve to pass into the pan below. This treatment shall be continued until no more material can be removed. The residue and the sides of the sieve shall then be thoroughly washed with water by means of a laboratory wash bottle.

In the washing process no artificial means, such as shot, rubbing with the finger, and so forth, shall be employed to force material through the sieve.

The order of sieves used shall be as follows: Wash the sample on the 325-mesh sieve to remove all fines, as this facilitates an accurate classification of the coarse material. The material passing this sieve may be concentrated by evaporation to dryness and weighed, or may be immediately thrown away and its amount

determined by difference. The residue on the 325-mesh sieve is transferred to a 65-mesh sieve and washed as described above. The material on the sieve is dried and weighed. The material passing the 65-mesh sieve is transferred to a 100-mesh sieve and washed and this process continued on the 150-, 200-, 260- and 325-mesh sieves, in order named, the residues on each being dried and weighed.

3. Moisture Content. Unless otherwise specified, the purchase price shall be based on moisture-free material and the moisture content shall be determined as follows: 50 grams of the sample (paragraph 1) are carefully weighed out as soon as the sample is taken and placed in an oven where a temperature between 105°C and 110°C is maintained with proper ventilation. The drying period shall be 24 hours and the loss in weight at the end of that period shall be reported as percentages of the dry weight.

4. Fusion Behavior. Test cones of the material shall be made of standard dimensions, *i. e.*, $2\frac{7}{8}$ inches high by $\frac{9}{16}$ inch diameter across base of one face. Cones of similar dimensions shall also be made of a mixture of 75 per cent by weight of the feldspar being tested and 25 per cent by weight of flint of standard specifications, as set forth in the accompanying specifications. The use of an organic bond, as dextrine or gum arabic, is permissible to insure the cones retaining form prior to fusion, but such added material must burn out completely and not affect the color of the material.

The fusion behavior of the different feldspars shall be as follows:

(a) Feldspars sold as potash feldspars shall fuse with or prior to standard Orton cone 8. The mixture of 75 per cent feldspar and 25 per cent standard flint shall fuse with or prior to standard Orton cone 9.

(b) Feldspars sold as soda feldspars shall fuse with or prior to standard Orton cone 7. The mixture of 75 per cent soda feldspar and 25 per cent standard flint shall fuse with or prior to cone 8.

(c) Feldspar sold as mixed or blended feldspar shall, if it contains more than 4 per cent soda, fuse prior to cone 7. The mixture of 75 per cent mixed or blended feldspar and 25 per cent standard flint shall fuse prior to cone 8.

5. Shipping Conditions. All material purchased under these specifications shall be shipped in clean, closed cars.

IV. Rejection.—The purchaser reserves the right to reject any portion or all of the material which does not conform to the above specifications in every particular and to return the rejected material to the manufacturer or seller for full credit at price charged F. O. B. point of delivery specified by the purchaser. If the material is to be replaced, a new order will be entered at prices, terms, and conditions acceptable to the purchaser.

Specifications Covering the Purchase of Pulverized Flint to Be Used in the Manufacture of Whiteware

I. Sample.—Same as paragraph 1, Feldspar Specifications.

II. Chemical Composition.—The material shall conform to the following limits of chemical composition:

| | |
|--|--------|
| SiO ₂ not less than | 99.60% |
| KNaO not more than | .15 |
| Fe ₂ O ₃ not more than | .05 |
| CaO not more than | .10 |
| MgO not more than | .10 |
| Al ₂ O ₃ not more than | .10 |

III. Physical Properties and Tests.—1. Color. The flint when formed into a standard cone and fired in a closed sagger or muffle to a temperature of cone 8 shall have a pure white color both on the surface and interior and shall be easily broken with the fingers, indicating no fusion.

2. Fineness of Grain. One hundred grams of the sample after being dried to constant weight at 105° C shall be tested for fineness of grain by the process set forth in paragraph 2b, Feldspar Specifications, and the residues on the various standard sieves shall not exceed the maximum totals as set forth in the following table:

| Standard Sieve Mesh per Linear Inch | Each Sieve Per cent | Residues | Max. Total Per cent |
|--|------------------------|----------|------------------------|
| 65 | 0.25 | | 0.00 |
| 100 | .25 | | .50 |
| 150 | 1.00 | | 1.50 |
| 200 | 2.50 | | 4.00 |
| 260 | 3.50 | | 7.50 |
| 325 | 45.0 | | 12.00 |

All percentages are calculated on dry basis.

3. Moisture Content. Unless otherwise specified the purchase price shall be based on moisture-free material and the moisture content shall be determined as described under paragraph 3, Feldspar Specifications.

4. Fusion Behavior. Test cones shall be made of the material according to standard dimensions, *i. e.*, $2\frac{7}{8}$ inches high by $\frac{9}{16}$ inch diameter across base of one face. An organic bond as dextrine or gum arabic is permissible to insure the cones retaining their form prior to fusion, but such added material must burn out completely and not affect the color of the material.

The flint when made into cones as described above shall not deform before cone 24.

5. Shipping Conditions. All material purchased under these specifications shall be shipped in clean, closed cars.

IV. Rejection.—The purchaser reserves the right to reject any portion or all of the material which does not conform to the above specifications in every particular and to return the rejected material to the manufacturer or seller for full credit at price charged F. O. B. point of delivery specified by the purchaser. If the material is to be replaced, a new order will be entered at prices, terms, and conditions acceptable to the purchaser.

OHIO STATE UNIVERSITY
COLUMBUS, OHIO

DISCUSSION

MR. T. A. KLINEFELTER: It is the experience of our firm that specifications of raw materials in general pay very decidedly. Flint and feldspar, as well as various types of clay, have proved no exception. Since, however, this is a field in which written specifications are not abundant, it is somewhat difficult to obtain material exactly meeting specifications by the occasional buyer who does have them. The supplier very naturally will prefer to deal with a buyer who is not "fussy."

It is the writer's belief that if written specifications were pretty generally in use by buyers, the material supplied to the trade would take a distinct advance in quality. It is sometimes hard to trace trouble to some one particular thing, and this is especially

true if no constant check is kept on material received. Moreover, without specifications one does not know exactly what he does want.

Every one is generally agreed that the fineness of grind of flint and feldspar has direct effect on vitrification, also that the fusion point of the feldspar varies greatly with the amount of flint impurity, and so forth. It is hard to find simpler, easier tests to check these two things than the ones proposed.

We have tested every car of feldspar and flint used at our plant for over four years for fineness of grinding under specifications somewhat more rigid than those proposed. It is our experience that the wet screen test gives a practical factory control plenty accurate enough for commercial purposes.

There is a human factor to be taken into account. For this reason the tests should be run preferably by one person. We have found, however, that if the tests are made by men of approximately the same degree of skill in handling apparatus in general, the difference is no more than would be shown by a second sample taken in a car and both car samples run by one person. We have found that 8 inch screens are much easier to handle than the smaller sizes, due to the fact that slopping over the sides is likely to occur in the case of the smaller sizes. Even if the screens finer than 200 mesh are not absolutely correct, the error introduced can not be as great as the difference which would be shown by two different samples from the same car.

A comparison of tests made on a considerable number of cars both at the grinding mills, dry, and the factory, wet, did not check at all. According to the dry tests at the mills all the cars were uniformly of fine grind. According to our tests a decided coarsening had taken place. The grinding mills admitted the shortening of time of grind but felt they were justified, due to their tests which showed no appreciable coarsening. It may be mentioned that the dry tests ran fully 10 per cent below the wet test figures, and variations between cars were very small. We felt, however, that the wet test more nearly covered our conditions, as cars which ran coarser according to our tests, gave heavier knockings on the body lawns.

The above experience does not really warrant condemning the

dry test method, as the difference may have been due to the different methods used in washing the material through the fine lawn at the start. In both methods the sample is wet-screened through the finest lawn. In our case it was washed through in the manner described in the above specifications. By personal observation later at the mill, the writer found that the first washing was being done by holding the screen under the water tap, allowing a fairly strong stream of water to run through. This may have resulted in forcing some material through which would not have passed through normally.

When the car checking was started considerable work was done to determine the accurate, and at the same time the most time-saving manner of handling the test. It was found that if the whole 100-gram sample were placed on the coarsest screen and washed through the whole series the result would run 3 to 4 per cent higher than if the sample were first washed out on the finest lawn before starting it through the series, and a much longer time was taken also. Moreover, a second washing of the whole set with clean fresh water would generally get an appreciable amount through which had not been washed out the first time. While it is true that prolonged washing with plenty of water would give as good results, the time was practically doubled, with less certainty of accuracy.

Two samples from the same car sample would almost invariably check within a few tenths of a per cent, if the samples were first washed through the fine lawn, while there would be two or three times as much difference by the other method, unless very prolonged washing with plenty of water was the rule.

After all, what the factory man wishes is to know whether or not he has been shipped a grade of material which is coarser than his standard, and the tests outlined above will do this for him with sufficient accuracy. He is not interested in accuracy to the fourth decimal place. Moreover, it should always be kept in mind that the sample run is perhaps only 1/2500 per cent of the whole car, so that differences due to sampling are certainly larger than microscopic differences in lawn mesh.

It was our experience that the fusion test on every car was not particularly necessary in case we were dealing with mills

handling but a single grade of rock from quarries of good size. On the other hand, it is absolutely necessary when buying blends or from companies handling different feldspars. The mixed feldspar-flint cone gives a very close check on the action of the feldspar, at least accurate enough for all commercial purposes. The pure spar fusion is not enough to tell readily whether or not the feldspar is carrying more flint than you are allowing for.

In general, it has been our experience that the tests for fineness of grain and fusion can be made readily and quickly and furnish good commercial control. An hour will cover the time spent in handling the sample from any car.

MR. O. O. BOWMAN: I would like to ask Professor Watts why he runs the material through the fine lawns first and then goes to the coarser lawns? What advantages are obtained by this method?

MR. A. S. WATTS: Replying to the inquiry from Mr. Bowman, I would make the following statement: The idea in passing materials through the finest sieve and then returning to the coarse sieve is in order to remove first all that material which can not be handled by sieves. When this is removed through the finest sieve the material remaining on the sieve is then transferred to the coarsest sieve, from it to the next finer and so on in order that the residues may remain on the sieves and be dried rapidly. If the order were reversed, passing from the finest to the coarsest, the amount of water used would be very large and the material separated would require evaporation of the water or at least long settling or decantation, either of which would be much more tedious than the method suggested.

It seems reasonable to accept the claim of feldspar and flint grinders that a moisture content of not to exceed 2 per cent be allowed. Any amount of water in excess of this, however, should be considered as an adulteration.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

A DIRECT READING OVERFLOW VOLUMETER* 1

BY H. G. SCHURECHT

A direct reading overflow volumeter was recently designed by the Ceramic Experiment Station of the Bureau of Mines, for clay testing and has been found to be very efficient. This apparatus consists of a glass bowl (see figures 1 and 2) containing an overflow tube sealed through the bottom and extending into the interior. Underneath is placed a special burette graduated with reverse reading to catch and measure the overflow.

Operation.—Open stopcock of burette, fill bowl with an excess of liquid above the orifice of the overflow tube and allow to drain to constant level. In filling the bowl, the liquid should be poured against the side with a beaker, thus preventing formation of air bubbles. The opening in the overflow tube is made small so as to retard flow of the liquid sufficiently to allow any bubbles which might form to break, and to allow the liquid to come to constant level. A special burette² graduated to read zero when completely drained above the stopcock is recommended, thus eliminating the necessity of adjusting the burette to zero reading for each operation. When the burette has completely drained, the stopcock is closed. After carefully wiping the saturated briquette it is lowered into the bowl by means of a spoon. The briquette displaces a volume of liquid equal to its bulk volume, causing the displaced liquid to rise above the overflow orifice and slowly flow down the tube into the burette where the volume of the briquette is directly measured. The brass spoon for immersing the briquette is suspended by means of a hook from the top of the bowl, keeping the bottom of the spoon about $\frac{1}{8}$ inch from the bottom, thus preventing the possible error due to accumu-

* Read February 3, 1920, at the meeting of the Society in Philadelphia.

¹ By permission of the Director, U. S. Bureau of Mines.

² The bowls and special burettes were made by the Columbus Scientific Glass Works, 101 Mithoff St., Columbus, Ohio.

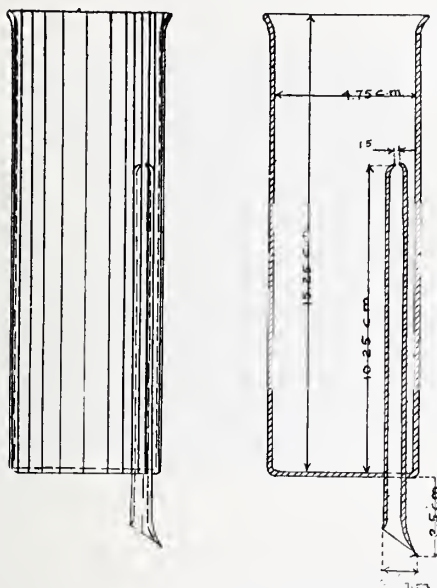


FIG. 1.—Volumetric bowl.

lation of dirt, which might change the volume of spoon immersed in case the spoon rested in the bottom of the bowl. The apparatus is allowed to drain about 10 minutes before reading. Reading of the burette is conveniently accomplished by the aid of a small magnifying glass and sliding gauge.

A battery of about 25 volumeters may be operated as a unit, thereby obviating the necessity of the operator remaining idle while the volumeters are draining. The liquid from the burette is caught in a copper trough and when kerosene is used is filtered through muslin, placed in a glass funnel, thus eliminating dirt from the oil.

Sources of Error.—The accuracy of the apparatus depends largely on its freedom from vibrations such as occur near machinery or are caused by the vibrations of floors, and the limits of accuracy within which the meniscus of the burette may be read. Vibrations produce surface waves, thereby causing an excess of liquid to flow through the overflow tube.

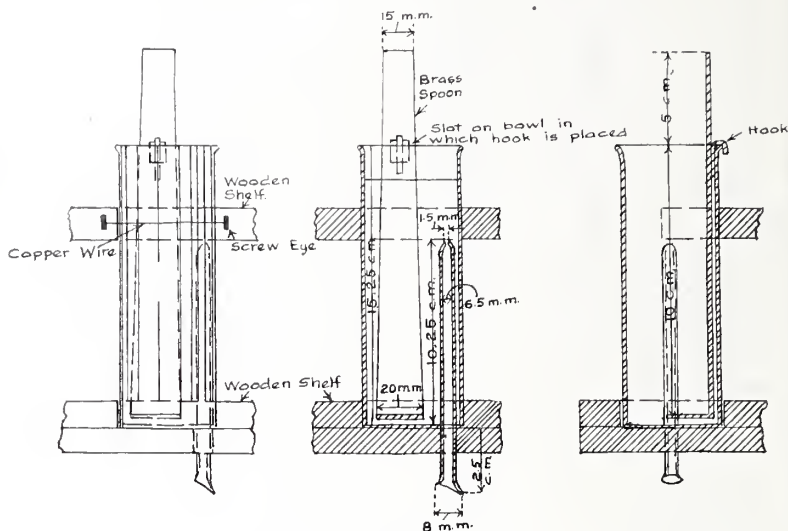


FIG. 2.—Glass volumetric bowl.

It was found that clamps, such as the universal type, could not be used to support the bowls unless an extremely short arm was used, as a long arm facilitated vibrations. In the Bureau of Mines ceramic laboratories no clamps are used for this apparatus, but instead well-bracketed wooden shelves to which the volumeters are held firmly by tightly twisted wires. The shelves are bolted to a 22-inch brick wall of the building, away from all vibrations of machinery and are not perceptibly affected by floor vibrations.

The diameter of the bowl should be kept as small as possible, thus increasing the accuracy of the determination. The bowl shown in figure 1 was designed for briquettes $1\frac{1}{8}$ inches \times $1\frac{1}{8}$ inches \times 4 inches, having a volume of about 80 cc.

Advantages over Other Types.—The error due to lodging of clay or grit in the stopper, which is one objection to the stoppered volumeter, is obviated in the above-described volumeter. Error due to liquid adhering to the briquette, which is possible in the Shaw¹ type, is prevented in the overflow type since the

¹ J. B. Shaw, "Direct Volume Determination in a Volumeter of the Pycnometer Type," *J. Am. Ceram. Soc.*, 2, 481 (1919).

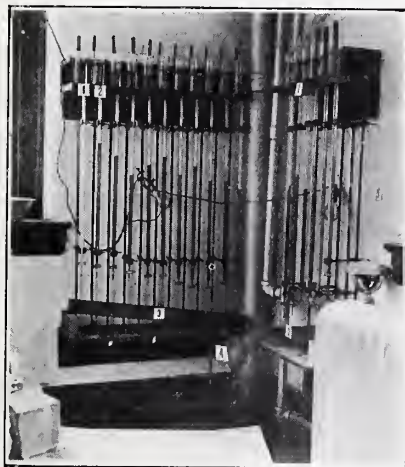


FIG. 3.—Battery of volumeter.

briquette may be wiped before immersion in the measuring liquid; also it is not necessary to determine the specific gravity of the immersion liquid as is the case with the pycnometer type. Corrections for the temperature of the liquid are also obviated. Ample time for draining (at least 10 minutes) should be allowed, when using the overflow volumeter.

Since the angle of capillarity of any liquid to a solid is constant for liquids of the same degree of purity and temperature and for solids of the same degree of cleanliness, the amount of liquid curving towards the sides of the bowl and burette are substantially constant in all cases, because these factors do not vary appreciably in the short time required for a determination. This is illustrated in the following checks made on a wrought iron bar of constant volume.

| 1 | 2 | 3 | 4 | 5 | 6 | Maximum variation from the mean, per cent |
|-------|-------|-------|-------|-------|-------|---|
| 77.80 | 77.80 | 77.85 | 77.90 | 77.80 | 77.85 | 0.0804 |

Comparing these determinations with those made on the pycnometer type volumeter,² the following results were obtained:

² H. G. Schurecht, "A Pycnometer Operated as a Volumeter," *J. Am. Ceram. Soc.*, **1**, 556 (1918).

| 1 | 2 | 3 | 4 | 5 | 6 | Maximum variation from the mean, per cent |
|-------|-------|-------|-------|-------|-------|---|
| 77.90 | 77.90 | 77.90 | 77.90 | 77.85 | 77.85 | 0.035 |

It appears from these results that the pycnometer is slightly more accurate than the overflow type, and where greater accuracy is desired or if the volumeter is to be used in a room near vibrating machinery, the pycnometer type is recommended.

However, the overflow volumeter is sufficiently accurate for clay testing¹ and the operating time using a battery of volumeters is about 60 per cent less than that required for the pycnometer volumeter even when time-saving devices such as charts and tables are used with the pycnometer type.

Since the error is considerably less than that allowable, the overflow volumeter is recommended for clay testing because of its speed and simplicity of construction and operation. In conclusion the author wishes to acknowledge his indebtedness to Mr. R. T. Stull for helpful suggestions in the construction of the apparatus.

CERAMIC LABORATORIES, U. S. BUREAU OF MINES
MINING EXPERIMENT STATION, COLUMBUS, OHIO

¹ In calculating the drying and burning shrinkages of 15 different clays it was found that the variation of the shrinkages of different briquettes of the same clay from the mean averaged about 1.10 per cent. This variation was due mostly to the variability in shrinkage of the briquettes themselves.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

A FACTORY METHOD FOR MEASURING THE VISCOSITY OF POT MADE GLASS DURING THE PROCESS OF MANUFACTURE TOGETHER WITH SOME DISCUSSION OF THE VALUE OF VISCOSITY DATA TO THE MANUFACTURER¹

BY EDWARD W. WASHBURN

I. Principle of the Method

1. **Introduction.**—Of the various methods which have been suggested or used for measuring the viscosity of highly viscous liquids, the one best adapted to the measurement of the viscosity of glass over a wide range of temperature, including the highest temperatures (ca. 1600° C), attainable in practice, is the method which may be descriptively designated as the "stirring method." In its simplest and most exact form the apparatus consists of two co-axial cylinders between which the liquid is placed. One of the cylinders is then rotated and the torque exerted upon the other, for a given angular velocity, is determined. From these data and the dimensions of the apparatus it is then possible to compute the viscosity of the liquid by means of the laws of hydrodynamics.

Viscosimeters based upon this general principle and differing only in the system of regulating or measuring the two variables torque and speed, have been used by a number of investigators.²

2. **A Laboratory Apparatus.**—An apparatus of this type in use in the laboratories at Illinois for measuring the viscosity of glass is shown in figures 1 and 2. The pot, cover, and stirring

¹ Received February 27, 1920.

² For example, the viscosimeters of Gurney, *Phys. Rev.*, **26**, 98 (1908); Clark, *Trans. Amer. Cer. Soc.*, **12**, 383 (1910); Stormer, *Ibid.*, **11**, 597 (1909); Veinberg and Smirnoff, *Jour. Russ. Phys. Chem. Soc.*, Phys. Div., **44**, 4 (1912); Harrington, *Phys. Rev.*, **8**, 739 (1916); and Field, Bureau of Mines, *Tech. Paper* 157 (1916).

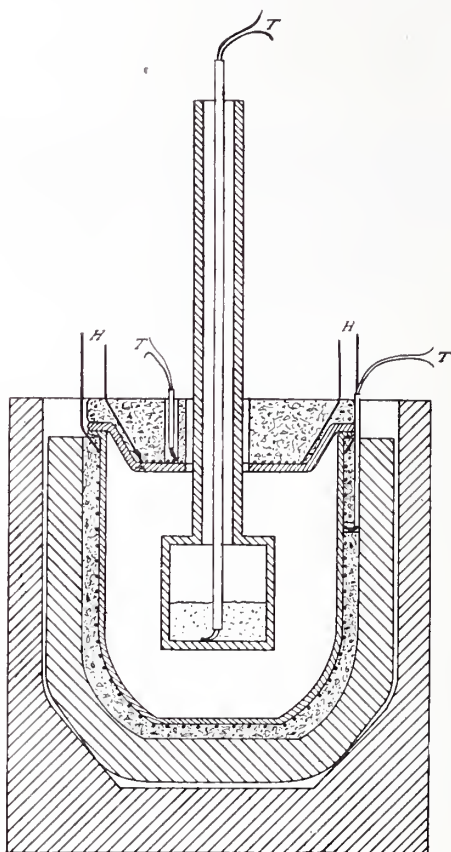


FIG. 1.—*H*, heating coils; *T*, thermocouples giving identical temperature readings.

cylinder are of porcelain and the heating coils of $\frac{3}{4}$ platinum. In using this apparatus the stirring cylinder is directly connected to the shaft of a specially designed motor and the power consumption P (or a proportional quantity) of the motor armature, when the angular velocity of the stirring cylinder is ω , is determined. If k is the calibration constant of the pot and P_0 is the power requirement for overcoming any mechanical and electrical

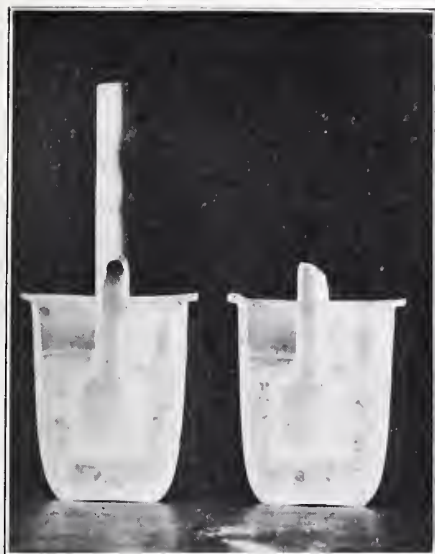


FIG. 2.—Cross-section of crucible, glass, and stirring cylinder.

friction in the driving mechanism, the viscosity η of the glass is then given by the expression ¹

$$\eta = \frac{k(P - P_0)}{\omega^2}.$$

With proper attention to details of design this apparatus is capable of a high degree of accuracy.² The calibration constant

¹ Or more exactly by the expression $\eta = f\left(\frac{P - P_0}{\omega^2}\right)$, the form of this function being determined by measurements with liquids of known viscosity. For all practical purposes, however, it is probable that equation (1) is sufficiently close to the truth for work with glass, provided proper choice is made of the calibrating liquid and due attention is given to centering the pot and correcting for the varying depth of the melted glass at different temperatures. In any case the method of calibration described below will take care of this matter.

² A detailed discussion of the theory of the method, the design and construction of the apparatus, the procedure in carrying out the measurements, and the results obtained with various types of glass will form the subject of a future publication.

k is determined with the aid of standardized solutions of a hexose in water, which at ordinary temperatures duplicate very exactly the properties of glass at high temperatures and thus constitute ideal calibrating liquids.

II. The Factory Apparatus

3. **General Features.**—From the foregoing brief outline of the laboratory apparatus it is clear that during the factory operation of stirring a pot made glass with a mechanical stirrer there exist nearly all of the essential elements of a viscosity apparatus on a large scale. To complete the apparatus it is only necessary to attach a wattmeter and a frequency meter (or other speed indicator) to the motor, and the necessary data for computing the complete viscosity-temperature curve of the glass can then be obtained during the ordinary stirring process without in any way interfering with that important operation. It is true that the data obtained in this way with the ordinary stirring equipment now in use will probably not be very accurate; but with certain improvements in the design of the stirring equipment, the accuracy attained can be very materially increased. The nature of some of these improvements will be briefly indicated, in the hope that some factory or institution having the necessary facilities will be interested in constructing a stirring outfit which will permit a thorough test of the proposed method on a factory scale.

4. **Measuring the Temperature of the "Metal."**—In correlating the viscosity measurements with the temperature of the molten glass in the pot, it is important that the method employed for measuring the temperature shall be accurate and shall represent as closely as may be the *average* temperature of the glass. If possible, a time-temperature curve should be automatically recorded covering the operation while stirring.

In a recent paper¹ on the "Use of Optical Pyrometers for Control of Optical-Glass Furnaces," Fenner has discussed some of the advantages and disadvantages of the optical pyrometer as an instrument for determining the average temperature of the

¹ Fenner, *Bull. Amer. Inst. Min. and Met. Eng.*, **151**, 1002 (1919); cf. also his paper on "The Technique of Optical Glass Melting," *Jour. Amer. Ceram. Soc.*, **2**, 138 (1919).

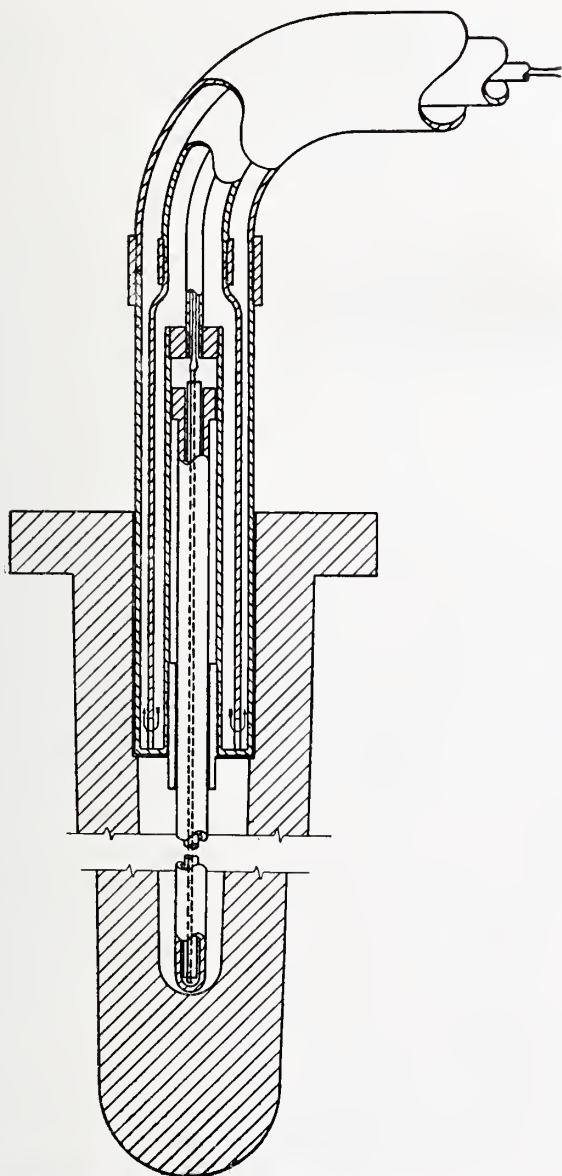


FIG. 3.—Showing method of inserting thermocouple in stirring thimble.

“metal.” It would seem after reading his discussion of the matter, that the most logical method of following the temperature of the “metal” *throughout the stirring operation* is by means of a properly protected thermocouple placed within the stirring thimble. There may be some reason why this is not practical on a large scale, but at all events the method would seem worthy of a trial.

A convenient arrangement for connecting the thermocouple to the stirring arm, so as to insure its proper placing in the stirring thimble each time, is illustrated in figure 3. The thermocouple sheath (*e. g.*, of dense refractory porcelain) is held in place in the end of the stirring arm by means of a screw, through which it has, however, free play in a vertical direction. The compensating leads which connect with the thermocouple wires within the water-cooled region may, if desired, be made of the special alloy employed by Fenner¹ in order to eliminate thermoelectric forces at the junction, although, even with copper leads, the total correction would amount to only about 10° C and may be made without introducing any appreciable error.

With this arrangement a recorder can be employed and thus a permanent record secured of the time-temperature curve throughout the stirring operation. The method of attaching the thermocouple suggested in figure 3 has the further advantage of permitting its easy replacement or its removal for annealing and calibrating, as frequently as may be desired.

5. The Motor.—The method may of course in principle be carried out with any type of motor but accuracy and convenience may both be increased by employing a motor whose design is adapted to the purpose in hand. It should be so constructed as to reduce both electrical and mechanical losses to a reasonable minimum and to render all such unavoidable losses as constant and as determinable as may be.

The details of the design and construction of the motor will vary with the nature of the power circuit of the factory and the character of the stirring machine itself and they may be safely left to the electrical manufacturers. The manufacturers should

¹ *C. p.*, p. 1005.

also "calibrate" any motor supplied for the above use. This calibration will consist in determining with the aid of a dynamometer the relation between the output of the motor and its power consumption, under various loads and at various speeds. Such data will obviously enable P_0 in equation (1) to be determined with increased accuracy.

6. The Wattmeter and the Speed Indicator.—The motor should be provided with a wattmeter¹ and with some type of speed indicator. For the speed indicator, either a simple revolution counter, a tachometer or some type of frequency meter may be employed. If the speed of the stirring thimble is controlled entirely at the motor, the readings of the speed indicator can be substituted directly for ω in equation (1), but if a change of gears or pulleys is employed in varying the speed of the stirring thimble, the readings of the speed indicator should be multiplied by the proper gear ratio; or the speed indicator may in such a case be transferred from the motor to the stirring arm itself.

Both the speed indicator and the wattmeter can be connected to recorders so that a permanent record of both P and ω throughout the run can be obtained, if desired.

7. The Stirring Machine.—To avoid power losses from belt slippage, the design of the stirring machine should preferably be such as to permit direct connection to the motor. For the highest accuracy only *ball bearings* and accurately cut gears should be employed and these should be water-cooled wherever necessary.

The path described by the stirring thimble in the glass is determined by what may be called the "setting" of the stirring machine and the points in the machine where this "setting" is made should be provided with such scales, or slots as may be necessary to enable a given setting to be made and reproduced accurately.

¹ A dynamometer on an extension of the motor shaft might, of course, be substituted for the wattmeter, but would be less convenient and more expensive, though more accurate. If a direct current motor with independent field excitation is employed, an ammeter in the armature circuit may be used instead of a wattmeter as under this arrangement the field losses, on a constant voltage, are without influence.

These are the main improvements in the stirring machine which are required in order to attain the highest degree of accuracy. It is evident that *constancy* in power loss within the machine itself is the *main* requirement, but reduction of this loss to a minimum is of course desirable.

III. Calibrating the Apparatus

8. **The Determination of P_0 .**—The determination of P_0 is carried out by operating the machine without the load on it. This should be done for each "setting" and for a series of speeds on each "setting." From the data thus obtained curves can be constructed which will enable P_0 to be read off for any condition of operation.

This method of evaluating P_0 obviously assumes that it is independent of the load. This will be very nearly the case in the stirring machine itself, if high-grade, well-lubricated ball bearings and gears are used in its construction.

In the case of the motor the power losses will, of course, vary with the load and the necessary corrections can be obtained from the calibration curve of the motor, which curve, as mentioned above, should be obtainable from the manufacturers. It should be noted, however, that if no correction is applied for the variation of motor losses with load, the error introduced need not be large since most of it will be automatically taken care of in the process of determining the constant k . All of it may, in fact, be thus taken care of, if for each "setting" of the machine, the constant k is determined as a function of the load as explained further below. Moreover, as the temperature of the "metal" in the pot falls, P becomes large in comparison with P_0 , so that errors in P_0 need not be of great consequence except during the initial period of the stirring operation.

9. **The Determination of k .**—Since in the usual method of conducting the stirring operation in a pot of glass the stirring thimble is not allowed to approach very close to the walls or to the bottom of the pot, the constant k should be practically independent of the size of the pot and of the depth of the "metal" in it. As regards the dimensions of the stirring thimble the con-

stant k may probably be taken as directly proportional to the area of the thimble in contact with the "metal" or, if the motion of the thimble has a vertical component, then to the *average* area so exposed. This matter, however, perhaps requires some experimental investigation and it may be found necessary or desirable to confine the viscosity measurements to those settings of the machine which do not give a vertical component to the stirring thimble.

The constant k may be expected to be to some extent a function of the "setting" of the machine, and its value should be determined for each "setting." It ought not theoretically to depend materially upon the speed of the machine, at all events not within the speed limits ordinarily used. Further light on these points will also be available as soon as the study of the mathematical theory of the operation has been completed.

The value of k *per square centimeter* (or, if the stirring thimbles are sufficiently uniform in shape, *per centimeter*) of thimble immersed is determined, for each regular "setting" of the machine, from the data obtained during the stirring operation on any pot of glass, the viscosity-temperature curve of which has been measured in the laboratory. The viscosity at a single temperature is, of course, all that is required in order to evaluate k , but a knowledge of the complete curve will permit check values to be obtained or will enable the operator to eliminate any appreciable error in P_0 arising from the assumption that this quantity is independent of load. This elimination is accomplished by taking the values of k as determined at different points along the viscosity-temperature curve and plotting them against the corresponding values of η . From the curve thus obtained the proper value of k may be selected for any subsequent run with the same stirring machine and motor.

IV. The Use of Viscosity Data in the Factory

10. **The Relation of Viscosity to Factory Operations.**—The three manufacturing operations which are connected with the viscosity of glass are (1) the elimination of seed (by fining); (2) the elimination of striae (by stirring); and (3) the avoidance of one class of "stones" (by rapid cooling through a certain "critical"

viscosity region). There are so few data available on the viscosities of industrial glasses which can be correlated with factory experience in the above operations that it would indeed be foolhardy to hazard at this time the formulation of rules of procedure, expressed in terms of viscosity, for carrying out or controlling any of the above operations. It may be worth while, however, to point out what appear to be some of the improvements in perfection of control which might conceivably result from a knowledge of the viscosities of pot made glasses.

11. As to Fining.—This operation is dependent upon the surface tension of the glass and upon its vapor pressure and density as well as upon its viscosity, so that a complete solution of this problem could not be given in terms of viscosity alone. For given values of the other three factors, however (and it may be that their influence does not vary very greatly from glass to glass), it might be possible, in terms of viscosity, to express in a perfectly general way for all glasses the maximum temperature which the metal should attain in order to insure successful fining.

12. As to Stirring.—As regards the stirring operation, which in the case of optical glass is largely depended upon to insure homogeneity in the melt, the directions for carrying out and controlling the details of this operation can at present be expressed only in terms of temperature or "color," and these directions have to be determined anew by the expensive process of trial and error, each time a significant change is made in the "batch." It seems entirely possible, however, to give complete directions for stirring procedure in terms of viscosity alone and thus to express them in a perfectly general way which should be largely, if not entirely, independent of the batch composition. In order to accomplish this, however, it would first be necessary to know the viscosity-temperature curves for a few representative glasses for which a definite and successful stirring procedure has been established so that the necessary correlation can be discovered.

Similarly in the case of certain types of pot made glass where diffusion and convection instead of stirring is largely depended upon to establish homogeneity, the requisite heat treatment for

all such cases should be capable of general expression in terms of the viscosity-time product or some simple function thereof.

13. **As to the Cooling Period.**—The application of viscosity data to the cooling period would probably not be so simple since the "critical region" for a glass depends not only upon the viscosity but also upon the compounds with respect to which the glass is supersaturated and upon the degree of supersaturation. It is entirely probable, however, that a comparison of the viscosity-temperature curves of different glasses over their "critical regions" would throw valuable light upon the nature of the factors which exercise a controlling influence upon this part of the cooling operation. Similar comments would obviously apply also to the annealing operation.

It should be pointed out, however, that the "stirring method" of measuring viscosity is not a convenient one to employ at annealing temperatures and should be replaced by a method of a different type which it is planned to discuss in a future publication. The whole subject of what may be called the low-temperature viscosity of glass may in fact be looked upon as a special field in itself. In addition to its relation to the devitrification and annealing behavior of glasses it has also an important bearing upon the development of the "colloidal" type of colored glasses and glazes and upon the permanency of such colors with time and heat treatment. The same is, of course, true of opal glasses. The surface flow of glass in the polishing operation is, of course, also a function of its low-temperature viscosity. Together with its coefficient of expansion the low-temperature viscosity of a glass also determines the character of the joint between the glass and a metal, such, for example, as the joint in an electric bulb where the connecting wires are sealed in. The resistance of a glass to sudden temperature changes is also largely determined by the same two factors.

DEPARTMENT OF CERAMIC ENGINEERING
UNIVERSITY OF ILLINOIS
URBANA, ILLINOIS

DISCUSSION

MR. G. V. McCAULEY: To one familiar with the wide variation of glass viscosities encountered in the temperature interval

from 1400°C to 700°C , the laboratory viscosimeter described above by Dr. Washburn will appeal strongly as the most adequate for use at the lower range of this temperature interval. Here the power consumed in stirring is relatively large and consequently the power loss in the mechanism would introduce less error. It recommends itself particularly for being adapted to the use of the thermocouple for low temperature measurements where the optical pyrometer becomes unreliable. Again, for temperatures below 900°C , where this method would be expected to supplant the more delicate elastic torque apparatus used by A. L. Field,¹ every part of the apparatus admits of rugged construction. Consequently sufficient torque can be applied either by a motor or by suspended weights to measure the very high viscosities encountered at temperatures suitable for annealing purposes.

The adaptation of the above apparatus to the measurement of pot made glass during the process of manufacture is, however, fraught with many difficulties. Some of these have been enumerated by Dr. Washburn. It seems worth while, however, to call attention to a certain dissimilarity existing between the laboratory apparatus described above and the stirring machines used in the glass industries.

It must be remembered that the actual stirring motion that is used in glass manufacture does not simulate the motion in the above-described laboratory viscosimeter. The motion of the stirring rod in the process of glass melting and fining is primarily a translatory motion through the glass. There is no rotation in general of the stirring rod about its own axis. Consequently the constant k of Dr. Washburn's calibration equation (1) would depend *materially* on the "setting" of the machine, *i. e.*, on the radius of the stirring circle.

Perhaps it would be possible to so construct a machine that would make the linear speed of the stirring rod through the glass independent of the radius of the stirring circle and dependent only on the speed of the motor. In this event the "setting" of the machine would not greatly influence the value of k , provided the stirring rod were kept far enough away from the pot wall and

¹ A. L. Field, Bureau of Mines, *Tech. Paper* 157.

were not allowed to describe too small a circle in the center of the pot.

While it may prove impossible to overcome all the obstacles necessary to make the apparatus yield accurate viscosity measurements at high temperature, it seems quite probable that it might be made to serve as an index of the proper viscosity at which the stirring should be stopped. Whether or not it can be made more sensitive for this purpose than the present method of temperature observation experience only can decide. As the viscosity of an average glass would increase about one-tenth of its value for a decrease in temperature of 5°C at the temperature where stirring is stopped, it would seem that with properly designed machinery a decrease of 5°C in the temperature of the glass, which is about the limit of accuracy of the optical pyrometer, should be easily observed by the resulting increase of 10 per cent in the power consumption of the stirring machine. At any rate the proposed method should entice some manufacturer who employs stirring machines to give it a trial to determine its possibilities.

CORNING GLASS WORKS
CORNING, NEW YORK

MR. A. E. WILLIAMS: In general determinations of the viscosity of glasses through the entire range of temperature from fining to their freezing point in the moulds is one of the most valuable set of determinations which can be made. The adapting of various glasses to the machines on which the finished products are to be manufactured depends to the greatest extent on this property, and much can be done in reproducing definite viscosity changes if the effect of various glass-making constituents on viscosity is known. A practical viscosity machine is, therefore, a great asset to the glass chemist.

The determination of the viscosity of optical glass melts during the process of manufacture would indeed be of great assistance, first, in determining the proper speed of stirring and, second, especially in determining the proper point to cease stirring. There is little doubt but what the striae, introduced by convection during cooling after stirring has ceased, promote the greatest loss of glass by coarse striae. The distance of travel of convection currents from the sides and bottom of the pots towards the center

depends to the greatest extent upon the viscosity of the glass when stirring ceases, and at present the time to cease stirring and cool rapidly is determined entirely by the temperature.

Experience shows that for each different glass there is a different temperature at which it is best to cease stirring and cool rapidly to the temperature where annealing may safely begin; also that for each type of glass, *i. e.*, flints, crowns, barium crowns, etc., this temperature represents apparently the same degree of viscosity. At present this temperature is located by simply trying melts at temperatures at which the glass has apparently the viscosity found best for that type of glass.

Actual measurement of the viscosity of the various glasses at the temperature stirring ceases would be very helpful in determining whether the viscosity of glasses of the same general type is the proper criterion to use in determining the rate of stirring as the cooling progresses and the point at which to cease stirring.

The practicability of measuring the temperature of the glass by placing a thermocouple within the stirring thimble is questionable because of the water-cooled thimble holder extending about six inches into the thimble and promoting a very considerable lag in temperature between the exterior of the thimble and the interior. The writer, however, has never actually determined the temperature of the glass in this manner.

BUREAU OF STANDARDS
WASHINGTON, D. C.

MR. R. J. MONTGOMERY: The use of the stirring machine, as a means of obtaining the viscosity of optical glass, is certainly of interest to all who manufacture this kind of glass. About a year ago, we tried to obtain some information on this subject, with the ordinary stirring machine. A wattmeter was placed on the circuit in an endeavor to obtain the variation of current used during the cooling period. We found that the power required to stir the glass as compared to the friction of the machine was so small that no variation could be detected between a furnace temperature of 2500 and 2000° F. We have also noticed that while stirring glass by hand and the power required varies very little with the temperature. This means that the forces involved are quite small and that a very sensitive apparatus would have to be con-

structed to obtain accurate readings. I am afraid that a machine of sufficient delicacy to give accurate readings would not be rugged enough to withstand handling by the labor ordinarily used around glass furnaces. The machines are often set at night with little competent supervision and exceptionally high-grade men would be required to take the necessary precautions to use a machine adequate for the work. A special test machine which would be set up and operated by laboratory men would certainly be of great value, and I hope that some day this will be done.

The use of a thermo-element inside of the stirring tube would also offer difficulties in practical operation. Occasionally the stirring tube breaks or cracks enough to allow the interior of the tube to fill with glass. Also it would be difficult to insert the water-cooled tube into the fire-clay stirring tube with a thermo-couple projecting from the end. The danger of breaking the protection tube of the couple would be great with ordinary glass plant labor.

I think the idea of temperature and viscosity measurement as given by Doctor Washburn could hardly be put into daily practice; but a test machine under proper supervision would be of great value in increasing our knowledge of certain properties of optical glass.

BAUSCH & LOMB OPTICAL Co.
ROCHESTER, NEW YORK

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

THE MANUFACTURE AND USES OF ROLLED OPTICAL GLASS*

BY H. S. ROBERTS AND J. C. HOSTETTER

Introductory

In melting optical glass, the material in the pot is most nearly homogeneous immediately after the rapid stirring at the highest temperature; if the melt could now be quenched rapidly to the solid condition the maximum yield of good glass would be secured. It is obviously quite impossible to quench rapidly such a large mass of material of low thermal conductivity. However, this ideal condition may be approached by removing the pot from the furnace and pouring the glass on to a large iron table, just as is done in making plate glass, and, by following the other usual plate glass processes of subsequent handling we may pass rapidly from melt to finished product.

As a method for the manufacture of optical glass in quantity, the casting and rolling process possesses certain other advantages over the older method of cooling the glass in the pot. The same pot is used many times, with a tremendous saving in pots and pot-arching capacity. The glass may be made on a large scale in the usual plate glass furnace, with a melting schedule of 27 hours, or even less if Morey's¹ method of stirring during the fill is employed. The yield per pot is considerably increased over the ordinary method of setting the pots out to cool. Large sheets of optical glass may be secured by this means, in thicknesses up to 2½ inches. The grinding and polishing necessary for critical examination can be done very quickly and cheaply. The large sheet may be cut readily with a wheel or diamond into rectangular blocks which are all within a small percentage of the same weight; consequently there is a much smaller loss to the user of such

* Received February 27, 1920.

¹ G. W. Morey, "A New Method of Optical Glass Manufacture," *J. Am. Ceram. Soc.*, 2, 146-150 (1919).

glass than when the ordinary optical glass is chipped to a certain weight for pressing. Finally, rolled optical glass can reach the final inspection within a week from the time the pot is taken from the furnace. The decided advantages of rolling optical glass are immediately manifest to those who are familiar with the time-consuming processes of initial inspection and chipping, the pressing of blocks, their slow annealing, the mounting of small blocks previous to grinding and polishing, the delays involved in removing pressing defects, and the final pressing and annealing necessary to form the glass into well-shaped blocks for the user.

It may be mentioned here that the production of optical glass was relatively low at the beginning of 1918. The development of rolled optical glass about this time by the Bausch and Lomb Optical Company and the Pittsburgh Plate Glass Company (the latter had for some time previously been using this method in the manufacture of unstirred spectacle flint and crown) came when the production of large quantities of usable glass was vital. It may be said that the development of this process of handling optical glass was mainly responsible for securing to the military authorities the necessary additional quantities so badly needed at that time.

The method of manufacturing rolled optical glass is essentially a combination of the melting process for optical glass and the casting and subsequent processes for ordinary plate glass, with such refinements as are necessary to insure a sufficiently high quality in the finished glass. Consequently the earlier operations, batch mixing, burning and glazing the pot, filling in the batch, and fining, are exactly those employed for optical glass that is to be cooled in the pot. These operations have been completely described elsewhere¹ and will not be repeated here. During the cooling and stirring period, however, a somewhat different procedure is indicated, because the melt is expected to yield an entire pot of glass that is *reasonably* free from striae, whereas in the case of glass cooled in the pot a portion of the glass is expected to be *wholly* free from striae, the rest being rejected.

¹ C. N. Fenner, "The Technique of Optical Glass Melting," *J. Am. Ceram. Soc.*, 2, 102-145 (1919). G. W. Morey, *op. cit.*

Cooling in the Furnace and Stirring

While the glass is hot, aluminous material is continually being dissolved from the pot, forming a layer, close to the pot wall, of viscous glass having an index of refraction different from that of the melt as a whole. Streamers of this material are carried, by convection and stirring, into the middle of the melt where they are gradually absorbed into the glass around them, the mixing process being accelerated by stirring. As the temperature falls, not only does the absorption of these streamers, or striae, proceed more slowly, but the increasing viscosity of the melt causes a greater tendency for them to be drawn into it by the movement of the stirring rod. As a result the average quality of the pot of glass as a whole deteriorates as the melt cools.

At the beginning of the stirring period the stirring rod is made to sweep rapidly over a circle nearly as large as the pot; as the cooling proceeds its speed is reduced and, if the glass is to be cooled in the pot, the diameter of the stirring circle is usually made less. This leaves the outer portion of the melt to cool without stirring and large quantities of ream unavoidably remain in it. When the melt is broken down this outer portion may be separated from the rest and rejected. Such a thorough separation is impossible in a rolled plate because of the unavoidable mixing that takes place as the glass is poured onto the casting table. Consequently the stirring should be carried on in such a way that the total amount of ream in the glass is a minimum. It has therefore been found better not to reduce the size of the stirring circle but to rely on stirring in a large circle at a low speed. Better results may undoubtedly be secured by the use of stirring machines that move the rod in a spiral rather than in a circle as is usually the case.

It is obvious that the melt is at its best in the early stages of cooling down from the fining period, and that the earlier thereafter it can be taken out of the pot, the fewer striae will be found in it. On the other hand, the glass must be sufficiently viscous, when it is poured on the casting table, to prevent it from splashing and foaming. It should consequently be cooled and stirred in the furnace until it has become sufficiently viscous. In this cooling process it is highly desirable to have the sides and bottom

of the pot lose heat faster than the top;¹ chilling the sides and bottom tends to cause the aluminous glass attached thereto to adhere to the pot in the casting which follows. If the pot is chilled rapidly from the top and if it should be cast while the bottom is still warm, the aluminous material from the pot is mixed more completely throughout the mass of metal in the subsequent rolling. Therefore, it is found desirable to keep a small flame playing across the top of the pot in the earlier stages of cooling, gradually cutting down the flame until the pot was removed from the furnace.

Casting and Rolling

The mechanical operations of casting and rolling are performed exactly as in making ordinary plate glass. The melt is poured out on an iron table and rolled into a sheet by passing a heavy roller over it, the thickness of the plate being determined by the thickness of the two steel strips on which the roller rides. As soon as the plate has become stiff enough to bear handling it is transferred, by sliding, into a heated kiln, which is then allowed to cool slowly to atmospheric temperature.

Considerable skill is involved in the operation of pouring and it has been found that workmen can be trained to pour the glass successfully at temperatures increasingly higher than that to which they have become accustomed. Temperatures at which certain glasses have been cast successfully are given in table 1.

TABLE 1—CASTING TEMPERATURES

| Type of glass | n_D | Deg. F | Deg. C |
|-------------------------|-------|--------|--------|
| Ordinary crown..... | 1.52 | 2200 | 1205 |
| Borosilicate crown..... | .515 | 2200 | 1205 |
| Barium crown..... | .57 | 2150 | 1175 |
| | .61 | 2200 | 1205 |
| Ordinary flint..... | .575 | 2225 | 1220 |
| | .616 | 2175 | 1190 |
| | .65 | 2100 | 1150 |
| Barium flint..... | .61 | 2150 | 1175 |

¹ The ideal condition which applies to the cooling of the melt whether it is to be set out or cast.

Cooling the Plate

The most desirable temperature for the kiln when the plate is placed in it varies somewhat with the kind of glass the plate is made of. It should be close to the "annealing temperature"¹ of the glass in question, and perhaps a little above it. Several of these annealing temperatures are given in table 2.

TABLE 2—ANNEALING TEMPERATURES²

| Type of glass | <i>n_D</i> | Deg. F | Deg. C |
|-------------------------|----------------------|--------|--------|
| Ordinary crown..... | 1.52 | 1060 | 570 |
| Borosilicate crown..... | .51 | 1095 | 590 |
| Barium crown..... | .57 | 1080 | 580 |
| | .61 | 1110 | 600 |
| Ordinary flint..... | .57 | 870 | 465 |
| | .61 | 850 | 455 |
| | .65 | 835 | 445 |

After the kiln is filled it is sealed up and cooled, an operation requiring from 3 to 6 days. Usually the fire is shut off and the kiln cools naturally; but in the cooling of very thick plates it is often necessary to retard the cooling somewhat by maintaining a fire in the kiln for a day or two. The actual rate of cooling at any temperature should not exceed that which would be employed in the annealing muffle for blocks of the same material and thickness as the plate.³ After the temperature has fallen below about 300° C (572° F) the cooling rate may be increased greatly without any danger of introducing permanent strain. It often happens that a faulty temperature distribution in the kiln causes plates to buckle or crack, even when the cooling rate has been sufficiently low to anneal them. In the theoretically perfect kiln the temperature over the whole of both surfaces should be the same at any instant. If one face is always warmer than the other, the differential contraction will cause the plate to buckle in such a way that the hotter face will become concave on cooling. This is because the glass has set while this difference of tempera-

¹ H. S. Roberts, "The Cooling of Optical Glass Melts," *J. Am. Ceram. Soc.*, **2**, 551 (1919).

² Taken from H. S. Roberts, *op. cit.*, p. 561.

³ Data and directions for the annealing of blocks of glass are to be published soon by Adams and Williamson.

ture exists, and as the two faces approach the same temperature, the hotter surface becomes smaller than the other, and the plate must become dished to accommodate it. Cracking is usually caused by a horizontal temperature difference, whose distribution and magnitude depend on the heat insulation of the kiln. Here again the plate sets while there is a temperature drop through it and is strained by the differential contraction as this drop is equalized on cooling. The result is usually that the corners crack off, though in severe cases cracks may extend clear across the plate.

Either of these effects of faulty temperature distribution may be remedied by changing the insulation of the kiln until the distribution is sufficiently uniform. Cracks in the kiln itself have been known to admit cold air, with results that were very puzzling till the crack was discovered.

After it has cooled nearly to atmospheric temperature the plate is taken out of the kiln and the more obvious defects, such as pot stones and large bubbles, are cut out of it. Care is taken that the remainder shall consist of rectangular sheets suitable for bedding on the polishing table.

Polishing

The end to be attained by polishing optical glass is merely that the whole interior of each piece be plainly visible in order that the defective portions may be found easily. Therefore isolated scratches which would ruin a plate glass window need cause no concern, provided the surface is not cloudy, because the surface is practically always ground off when the glass is worked into a lens or prism. As in plate glass work, both sides are roughed with sand and emery and polished with rouge.

Examination

After being polished the plate is usually placed in a vertical frame near a window for examination. Both faces are cleaned with a cloth and the defective parts outlined on the surface of the plate with a crayon in order that they may be found readily and rejected when the plate is cut up. The usual rigid examination in parallel light may be made on the plate as a whole, pro-

vided that the apparatus is modified so that any portion of the plate may be placed between the two lenses.

After passing the above inspection, glass made in this manner may appear absolutely free from striae when examined through the flats, but still show some parallel layers when examined through the ends, although a certain proportion of the glass so made may show no striae at all, even when examined in the latter direction. It is obvious, therefore, that the uses of this kind of glass are somewhat restricted. In what follows, however, it will be shown that such glass is still usable for a great variety of purposes if a certain technique, which recognizes the presence of parallel striae, is followed in making the lenses or prisms from it.

The glass as it reaches the wareroom is sufficiently well annealed to permit of cutting into variously sized square blocks of such weight that one blank can be pressed from each. Or, if prisms are to be cut from the blocks, the size of the latter may be made such that a definite number can be cut from each, making due allowance for the width of the saw cut and the amount lost in grinding and polishing.

If the glass is to be pressed into blanks, it is ready to be turned over to the user as soon as it is cut up. If lenses or prisms are to be cut directly from it, the glass must, in most cases, be given a more careful annealing. This is done in the usual manner, with an annealing muffle.

Uses of Rolled Optical Glass

Because of the fact that rolled optical glass unavoidably contains a certain amount of parallel layers of glass differing in index from the main portion, it is necessary to take this factor into consideration when working up the glass into finished optical systems. The best results are secured when the path of the light is normal to the parallel layers. When the glass is used in this way, there is a slight decrease in transmission, but aside from this the glass is very little, if any, different in behavior from the ordinary optical glass. However, if used without regard to the presence of the parallel layers, difficulties may be encountered. The precautions to be taken when using rolled optical glass will be presented below. In this connection we may quote here

some results obtained by Lieut. Comdr. A. A. Michelson, at the Bureau of Standards, on the effect of striae.¹ He divided striae into two classes:

"First, those which appear, under proper conditions, as isolated bright streaks on the dark background, and, second, those in which such bright streaks are very numerous and run into one another forming bright but irregularly continuous bands. Even a superficial examination of the two kinds shows that the optical qualities of glass containing the first type are practically unaffected by the striae, while the latter specimens are *in general* unfitted for use in optical instruments." We may note here that striae in rolled optical glass which has been well stirred fall in Michelson's first class, and therefore his conclusions regarding this case apply in their entirety to rolled optical glass.

In regard to striae of the first class (which include those found in rolled optical glass), he concluded that: "... isolated striae are of no more importance than are the bubbles found in some of the best telescope objectives. In case of striae of the second class this is not true in general, so that it is not desirable to attempt to utilize such glass for optical purposes where a high resolving power is required. Nevertheless, it is important to add that for many purposes, such as for binoculars, gun-sight telescopes, periscopes, etc., such glass may give excellent results if the planes of striation are *perpendicular to the line of sight*. Such glass should not be used for prisms."²

We may also quote here a foot-note from the same paper which is of interest in this connection: "A specimen of glass exceptionally badly striated when viewed end on was placed between collimator and observing telescope of the spectroscope (aperture 2 inches) which gives admirable definition. When the specimen was introduced with the striations perpendicular to the line of sight, no deterioration of the definition was observed. Hence a lens of such glass would perform quite as well as if the striation were not present."

¹ Bur. Standards, *Bull.* 15, 41-45 (*Sci. Paper* 333) (1919).

² Our conclusion in regard to prisms from such glass differs somewhat from his, but the difference is not irreconcilable if the prism is cut with respect to the direction of the striae, as will be shown.

Lenses.—Attempts to make lenses by cutting and grinding directly from the rolled sheets were not always successful. In

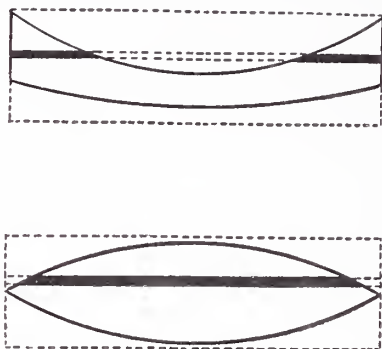


FIG. 1.—The manner in which layers of striae may cause concentric circles to appear in the finished lens.

one particular instance, finished lenses gave a field in which concentric rings appeared. This was especially true of the negative flint lens; similar trouble did not develop, at least not to such a large extent, in the case of the positive or crown element. At first this difficulty was thought to be caused by defective grinding and polishing, but later it was traced to the presence of heavy layers in the glass.¹ That such trouble might readily arise in this



FIG. 2.—The concentric circles of Fig. 1 may be avoided by pressing the glass into the shape of the lens.

manner is evidenced by the fact that in grinding out the negative lens from a block of glass the heavy layers, which are usually near the center of the plate, are cut across, whereas in the case of the positive lens, these layers are either not cut at all or, if cut,

¹ It should be stated here, however, that the rolled flint which was responsible for the trouble just described had never been intended for precision work, but was of the stock used regularly for bifocal lenses. The inspection which such glass received is, of course, much less severe than that given glass intended for precision instruments. Even so, the percentage of rejection for this cause was comparatively low.

the prism thus formed is near the edge of the field. Reference to figure 1 will make this clear.

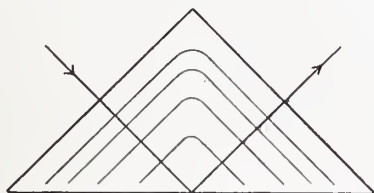


FIG. 3.—A telescope prism pressed from rolled glass. The light rays cross the films of striae at right angles.

The above-mentioned difficulties were overcome completely by pressing out the lens blanks, instead of cutting them directly from larger pieces. In this manner, the layers within the glass are curved in such a way that they are not cut in the finished lens, as will be seen by reference to figure 2 which shows the cross-section of a negative lens made in this manner.

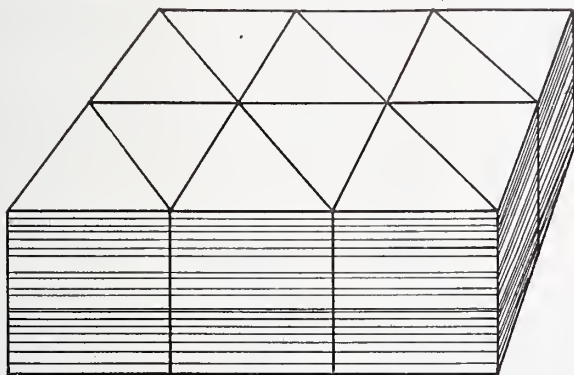


FIG. 4.—Prism blanks cut from rolled glass. Here the light rays are parallel to the striations.

Lens systems made up from rolled optical glass in this manner were found to make satisfactory low-power instruments such as single-unit sights, binoculars, and trench periscopes, but, considering the results obtained by such an authority as Professor Michelson, quoted above, it is quite obvious that rolled glass may also be suitable for high-power precision instruments.

Prisms.—In manufacturing prisms from rolled optical glass we must again take into consideration the fact that such glass may have parallel layers within it. Prisms may be made from this glass either by pressing or by cutting, but in the latter case we must know whether there is to be one reflection within the prism or two, and methods of cutting have been worked out in a fairly satisfactory manner for both classes.

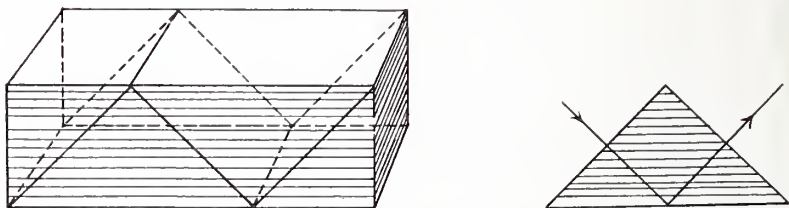


FIG. 5.—Taylor's method for cutting prism blanks, where there is to be but one reflection within the prism.

If the glass is to be pressed into prisms the parallel layers should be bent in such a manner that the light path is always normal to them. A battery commander telescope prism, that actually passed the government test when in the instrument, was pressed from rolled borosilicate in such a manner that when examined in parallel light the striae were bent as indicated in figure 3.

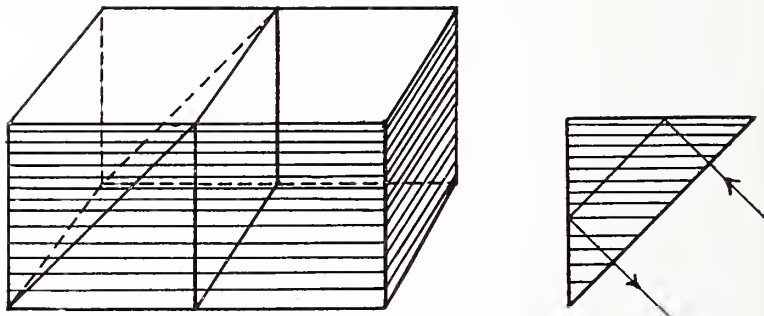


FIG. 6.—Taylor's method for cutting prism blanks, where there are to be two reflections within the prism.

In cutting prisms from rolled glass they may be sawed out as indicated in figure 4, and prisms cut in this manner were found to give a fairly satisfactory definition.

In addition to this method of cutting there is another method suggested by Mr. W. H. Taylor, of the Bureau of Standards, which yields a prism with the striae so arranged that the light path is always at 45 degrees to them. If there is only one reflection within the prism, as is the case for the periscope prism, the method of cutting is illustrated in figure 5; but if there are two reflections within the prism as in the case of the binocular prism, the method of cutting is indicated in figure 6. Both of these methods have worked out with some degree of success in practice.

Summary and Conclusions

Rolled optical glass is manufactured by a process that combines the stirring and earlier processes used for ordinary optical glass, with the casting and subsequent processes ordinarily used in the manufacture of rolled plate glass. The glass obtained is characterized by the presence of striae in the form of plane, parallel films, which are in general invisible unless viewed edgewise. Optical systems manufactured from rolled glass should therefore be designed so that the path of light rays cuts the striations in a direction that is as nearly as possible normal to the direction of the striations themselves.

The methods of manufacture and inspection are described and a discussion given of the manner of forming the glass into blanks for lenses and prisms.

This method lends itself admirably to large-scale manufacture of glass that is suitable for most of the optical instruments used in warfare, for photographic lenses, field glasses, spectacles and low-precision instruments in general. For instruments of the highest precision, recourse must still be had to the older process of cooling the glass in the pot.

GEOPHYSICAL LABORATORY
CARNEGIE INSTITUTION OF WASHINGTON
March, 1920

CERAMIC ABSTRACTS

General

The commercial synthesis of sillimanite. ANDREW MALINOVZKY. *Chem. and Met. Eng.*, **22**, 851 (1920).—A description of a cupola process for fusing alumina and silica to form sillimanite crystals. The reactions consist of forming carbides under reducing and combusting them under oxidizing conditions. (See *Jour. Amer. Ceram. Soc.*, **3**, 40-68 (1920).)

A. J. LAMBERT.

The potash deposits of Germany. STAFF ARTICLE. *Chem. and Met. Eng.*, **20**, 945 (1920).—The potash deposits of Germany have been estimated to contain about 2,000,000,000 metric tons of potash (K_2O), a quantity sufficient to supply the world for 2,000 years at the present rate of consumption. These beds have furnished practically the entire world's supply of potash for many years.

A. J. LAMBERT.

Diatomaceous or infusorial earth. W. C. PHALEN. *Chem. and Met. Eng.*, **21**, 981 (1920).—Diatomaceous earth is more commonly known as infusorial earth, and is sometimes referred to by its German name "kieselguhr." It is also, though erroneously, called tripoli. It is composed of the siliceous remains of minute aquatic plants known as diatoms. In chemical composition, diatomaceous earth is a hydrous silica or opal, but as a rule it contains a considerable quantity of earthy impurities. The silica runs from 65 to 86 per cent in most samples. The chief impurity is clay. Deposits are found in many states, the most important being those in California.

A. J. LAMBERT.

Automatic apparatus for intermittent testing. G. W. VINAL AND L. M. RITCHIE. Bur. of Standards, *Tech. Paper* 171.—This apparatus has been devised to meet the needs of the Bureau of Standards in making tests of dry cells and storage batteries, but is applicable to nearly any form of intermittent testing requiring the closing of electrical circuits at regular time intervals. The particular advantages of this type of apparatus for making these tests are: (1) Elimination of rapidly moving parts; (2) accuracy of the time intervals; (3) possibility of making a number of different tests simultaneously with the same apparatus.

R. N. BOORMAN.

The British china-clay industry. ANON. *Chem. and Met. Eng.*, **23**, 147 (1920).—The china-clay export trade of England is beginning to revive after the severe blow dealt it by the war. Of the total production of 964,000

tons in 1912 over 661,000 tons were exported. In 1918 the production dropped to 465,325 tons and the export to 232,464 tons. Last year the export rose to 286,543 tons. With the gradual return of freights to normal the regaining of the American market by British clay shippers seems only a matter of time. As the American market accounts for nearly half of the normal china-clay export trade of the United Kingdom, and was actually more than half in 1914, it is important to the British industry that this business be recovered. All the stocks of china-clay on the continent are practically exhausted, and the replacement of those stocks, apart from running supplies, must absorb large quantities in the very near future.

R. N. BOORMAN.

PATENTS

Pug mill knife. FRED O. RUSH. U. S. 1,347,876, July 27, 1920. A pug mill knife comprising in combination a blade and separate shank, the shank having an irregular integrally formed portion for nonrotatively mounting the shank in the mill shaft, and means including a plurality of members arranged at substantially the same distance from the axis of the shaft for securing the blade to the shank.

Apparatus for treating silicates. WALTER GLAESER. U. S. 1,347,024, July 20, 1920. The combination of a stationary furnace chamber, a stationary stack chamber spaced therefrom, a rotary tubular shell connecting and affording communication between the chambers, a kiln mounted in the shell and extending through the chambers and projecting beyond the front wall of the furnace chamber, and receiving means associated with the projecting end of the kiln beyond the wall of the furnace chamber.

Tunnel kiln. PAUL A. MEEHAN. U. S. 1,348,510, August 3, 1920. In a kiln the combination with a kiln chamber having a ware inlet and egress port and means for maintaining a high temperature zone displaced longitudinally of the kiln from the port, of a carrier adapted to reciprocate in the kiln to alternately carry ware back and forth between the port and the zone.

Tunnel kiln. PAUL A. MEEHAN. U. S. 1,348,511, August 3, 1920. A combustion chamber structure for kiln heating provided at one end with air and fuel inlets and an outlet for products of combustion, and formed internally with two passages or chambers extending longitudinally of the structure and communicating, one with said inlets and the other with the outlets at the one end of the structure, and in communication with one another at the opposite end of the structure.

Drier. GUILFORD L. SPENCER. U. S. 1,348,757, August 3, 1920. A dryer, including a casing, a housing positioned below such casing, a tube extending from the lower end of the casing and terminating adjacent the top of the same and communicating at its lower end with the housing, a partition

dividing the casing into an upper and a lower compartment, the partition being formed with openings, capsules positioned within such openings, and a source of suction connected to the lower of these compartments, the capsules seating against the opening in the partition in such a manner as to form an air-tight joint.

Smelting furnace and the like. JAMES GAUNT. U. S. 1,344,878, June 29, 1920. This furnace has a cylindrical casing open at its upper and lower ends and provided on the inner side of its wall with vertical, radially disposed spaced ribs; a cover on upper end of the casing, a hopper mounted on the cover; a grate, grate-supporting means with which the lower end of the casing is provided; a refractory lining in the casing supported also on the grate-supporting means and co-acting with said spaced ribs to form a circuitous air conduit around the lining and to a point below the grate; an air blast pipe connected to the casing, a crucible mounted on the center of the grate and a detachable closure being hollowed in its upper side and hence forming a chamber to conduct the air blast from the conduit to air spaces in the grate.

Mechanical Mixer and Drier. HUDSON H. BUBAR. U. S. 1,344,675, June 29, 1920. An apparatus comprising a container having a bottom provided with a contralongitudinal arc-shaped channel and channels disposed parallel therewith on opposite sides thereof, a rotary shaft carrying spiral blades disposed over the central channel and rotary shafts carrying spiral blades disposed over the side channels, and a mean for rotating the central shaft in a direction opposite to the rotation of the side shafts, the path of blades of the central shaft interlapping with the paths of blades of the side shafts.

Method of Deflocculating Solid Substances. EDWARD GOODRICH AEBESON. U. S. 1,345,306, June 29, 1920. A method of deflocculating graphite, consisting in subjecting the same, mixed with a deflocculating agent and in paste form, to a process of attrition, the total moisture contents of charge being less than 32 per cent by weight.

Furnace. JOSEPH H. ROACH. U. S. 1,346,464, July 13, 1920. A grate for forced draft furnaces comprising a plurality of reciprocatably mounted grate bars, a partition dividing the supporting structure into separate air intake conduits, co-acting members carried by the bars forming a constricted passage by way of the bar structure between the conduits, and means to reciprocate the bars without interfering with the constricted passages.

Furnace construction. JOSEPH F. TUTEIN. U. S. 1,345,652, July 6, 1920. This describes furnace structure, the combination, with a furnace chamber, a mechanical fuel feed, and a speed-changing device applied to the fuel feed, of an automatic control for the speed-changing device including a movable element subject in opposite directions to furnace-chamber pressure and to atmospheric pressure.

C. M. SAEGER.

Refractories

Binders for ceramic colors. ANON. *Keram. Rundschau*, 28, 239 (1920).

—The following materials are suggested as substitutes for sugar in ceramic colors: glycerine, dextrine, gum tragacanth, gum arabic, fine white clay, and Na_2SiO_3 . The above materials are mixed with a coloring oxide mixt. containing considerable flux such as feldspar or glaze. A special binder used for underglaze colors is prepared by boiling thoroughly a mixt. of garlic and onions and filtering off the liquid. This liquid is then mixed with the coloring oxides and since it does not combine with the glaze leaves sharp lines in the design.

H. G. SCHURECHT.

Firing kilns with wood. ANON. *Sprechaal*, 53, 252 (1920).—Owing to the coal shortage, the use of wood in place of coal is becoming necessary. One source of supply is tree stumps which may be removed by blasting, with a machine and by hand. Stumps removed by blasting contain considerable sand and dirt and are not as desirable as the cleaner product removed by hand. Roots as a rule are unfit for firing kilns. The wood is cut in 1 m. lengths and the thickness is about 8–10 cm. Sound wood gives good results in firing, comparing favorably with brown coal.

H. G. SCHURECHT.

Refractories for glass furnaces and melting walls. J. BALDERMANN. *Tonind. Ztg.*, 44, 581–82, 612 (1920).—Grog should never be greater than 3 mm. and should be fired high enough to remove all of the shrinkage. Often coarse quartz is added to glass refractories which is poor practice since these particles are dissolved by the glass, leaving a honeycombed effect. Old pots make excellent grog since all of the shrinkage has been burned out.

H. G. SCHURECHT.

Light weight refractories. ANON. *Tonind. Ztg.*, 44, 718 (1920).—Good insulators for furnaces have for some time been made by adding sawdust, coal and kieselguhr to clay and firing same. In Asia Minor there is a type of kieselguhr which has sufficient strength so that it may be sawed and cut into brick. Such brick need not be fired. It is suggested that this material would make excellent insulation for buildings.

H. G. SCHURECHT.

Furnace linings with magnesium hydroxide. ANON. *Keram. Rundschau*, 28, 260 (1920).—Magnesite brick may be made by using 10–15 per cent $\text{Mg}(\text{OH})_2$ with dead burned magnesite. Brick are pressed with a pressure equal to 800 atms. To prevent cracks the brick should be kept damp and dried slowly. Brick should be laid with close joints using 90–92 parts dead burned magnesite and 10–8 parts of coal tar as a binder.

H. G. SCHURECHT.

Investigations on zirconium. J. W. MARDEN AND M. N. RICH. *Jour. Ind. & Eng. Chem.*, 12, 651–656 (1920).—The most satisfactory method of producing

nearly pure ZrO_2 was as follows: One pound or a larger quantity of ore was slowly heated with four parts of concentrated H_2SO_4 until free of fumes and the temperature gradually raised to 650°C . After cooling the flour-like residue was extracted with 50 parts of cold water, filtered, and sodium carbonate added to neutralize any free acid until the zirconium hydroxide just began to form. The solution was allowed to stand 3 or 4 days, during which time the basic sulfate $4\text{ZrO}_2 \cdot 3\text{SO}_3 \cdot 14\text{H}_2\text{O}$ gradually separated out. When this was ignited a very high-grade ZrO_2 was obtained, which in one case contained 99.84 per cent ZrO_2 and was free from any determinable trace of SiO_2 . Exclusive of labor and equipment the cost for the production of 1 lb. of oxide by this method was about twenty cents. Data are given also on the preparation of pure K_2ZrF_6 , the preparation and properties of zirconium metal, and the methods for analysis of zirconium ores. R. N. BOORMAN.

PATENTS

Refractory article and method of making the same. SILAS C. LINBARGER. U. S. 1,345,377, July 6, 1920. This describes a refractory article having a body portion consisting substantially of fire-clay, a facing portion containing a substantial portion of silicon carbide, and an intermediate portion containing silicon carbide in such decreasing amounts from the facing portion as will give a graduated and increasing coefficient of expansion from the facing portion to the body portion.

Light-weight refractory brick. ROSS C. PURDY AND MILTON F. BEECHER. U. S. 1,345,632, July 6, 1920. A composition of matter for a porous brick, comprising a burned refractory lignite clay mass.

Boiler arch and wall and means for supporting same. LUTHER S. SHAW. U. S. 1,345,410, July 6, 1920. This describes a setting made with the combination of a plurality of beams suitably supported, a plurality of bolts suspended from the beams fitted with relatively large disks or nuts for supporting an arch or wall, a platform for temporarily supporting an arch or wall of unburned fire-brick material, a plurality of bolts detachably connected with the first-named bolts by the disks for suspending the platform during the process of burning the fire-brick material, an arch or wall suspended from the first-named bolts, formed of unburned fire-brick material upon the platform and baked while temporarily supported thereby. C. M. SAEGER.

Glass

Science and the glass industry. C. H. KERR. *Chem. Eng.*, 28, 107-11 (1920).—While the developments along mechanical lines, especially in automatic machinery, has been marvelous, there has not been a corresponding application of scientific knowledge. However, the importance of the science of glass making is now being more fully appreciated and a real evolution has started. Better fundamental knowledge is now available to help such progress. C. H. KERR.

Chemical glassware, the resistant properties of. (a) The resistant properties of some types of foreign glassware. J. D. CAUWOOD AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 2, 219-35 (1918).—B. Further investigation on chemical glassware. CONSTANCE M. M. MUIRHEAD AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 3, 129-31 (1919).—The tables on pages 418 and 419 of this volume of the JOURNAL belong with the abstract given on page 420 under the above title.

EDITOR.

Progress in optical glass manufacture. ANON. *Chem. and Met. Eng.*, 23, 158 (1920).—A triumph of American ingenuity is the manufacture of optical glass. Prior to the war practically all this material was produced abroad. Lenses up to 20 in. in diameter are now made in this country and larger ones contemplated.

R. N. BOORMAN.

Composition of hollow glassware for tanks. *Schnurpfeil's Review for Glass Works*, 4, 613.—Sand, 1,000 lbs., soda ash, 320 lbs., lime, 200 lbs., saltpetre 10 lbs., cullet 200 lbs., nickel oxide $\frac{1}{5}$ oz.

R. J. MONTGOMERY.

Composition of glass for tumblers. *Schnurpfeil's Review for Glass Works*, 4, 633.—Sand 1,000, soda ash 330, lime 160, barytes 80, saltpetre 25, arsenic 3, manganese 1.

R. J. MONTGOMERY.

Composition of glass for pressed ware. *Schnurpfeil's Review for Glass Works*, 4, 633.—Sand 100 lbs., soda ash 33 lbs., barytes 15 lbs., lime 12 lbs., saltpetre 3 lbs., arsenic 8 oz., manganese 3 oz.

R. J. MONTGOMERY.

Composition of glass with the appearance of mother-of-pearl. *Schnurpfeil's Review for Glass Works*, 4, 581.—Sand 100, soda ash 25, lead 15, nitrate of potash 25, cryolite $1\frac{1}{2}$, bone ash 5, borax 25, nitrate of bismuth 3, nitrate of copper $\frac{1}{4}$, fluorspar $1\frac{1}{2}$.

R. J. MONTGOMERY.

Composition of glass for electric lamp bulbs. *Schnurpfeil's Review for Glass Works*, 4, 583.—Sand 100, lead 36, lime 8, soda ash 30, nitrate of potash 3, borax 1.

R. J. MONTGOMERY.

Composition of watch glass. *Schnurpfeil's Review for Glass Works*, 4, 583.—Sand 100, lime 15, soda ash 33, nitrate of potash 5, lead 5, arsenic $\frac{1}{2}$, manganese $\frac{1}{4}$, antimony $\frac{1}{4}$.

R. J. MONTGOMERY.

Composition of opal glass for illuminating glassware. *Schnurpfeil's Review for Glass Works*, 4, 599.—Sand 100, soda ash 30, fluorspar 20, feldspar 35, cryolite 8, manganese $\frac{1}{4}$.

R. J. MONTGOMERY.

Analysis of a Bohemian cut glass. *Schnurpfeil's Review for Glass Works*, 4, 613.— SiO_2 70.16, Al_2O_3 1.01, CaO 12.11, MgO 0.39, K_2O 14.98, Na_2O 2.03.

R. J. MONTGOMERY.

Composition of green lead glass without potash. *Schnurpfeil's Review for Glass Works*, 4, 615.—Sand 100 lbs., soda ash 30 lbs., saltpetre 5 lbs., lead 48 lbs., red bichromate of potash 19 oz., copper oxide 6 oz., iron oxide 4 oz.

R. J. MONTGOMERY.

Composition of glass for vacuum bottles. *Schnurpfeil's Review for Glass Works*, 4, 615.—Sand 100, soda ash 36, borax 4, alumina 4, lime 20, saltpetre 2.

R. J. MONTGOMERY.

The importance of sulphate of soda in the glass industry during the war. *Schnurpfeil's Review for Glass Works*, 4, 625.—The substitution of soda for potash caused considerable trouble. The use of sulphate of soda gives a glass of poorer quality. The iron content is 0.01 to 0.08 per cent, which is higher than that of the carbonates of soda or potash. Sulphate made in lead pans is freer from iron than that made in iron ones. The salt cake batch attacks the pot more and is more difficult to melt. 4 lbs. of powdered anthracite or charcoal are used for 80 lbs. of sulphate of soda. The correct amount is important.

R. J. MONTGOMERY.

Composition of brown glass. *Schnurpfeil's Review for Glass Works*, 4, 631.—Sand 100, soda ash 33, fluorspar 2, lime 20, graphite 4 to 5, manganese $1\frac{1}{4}$.

R. J. MONTGOMERY.

Composition of thermometer glass. *Schnurpfeil's Review for Glass Works*, 4, 633.—Sand 100, soda ash 36, lime 20, zinc oxide 10, alumina 6, borax 6.

R. J. MONTGOMERY.

PATENTS

Method and apparatus for the manufacture of pressed sheet glass products. FRANK L. O. WADSWORTH. U. S. 1,346,571, July 13, 1920. The method of manufacturing pressed glass sheets or plates which comprises the preliminary spreading of the molten material to sheet form, the subsequent reheating of one side of spread sheet to a substantially uniform temperature over the entire area to be subjected to pressing operations and the final pressing of the reheated surface. The apparatus for the manufacture of pressed glass plates or sheets which comprises a glass receiving table, a spreading mechanism, a furnace, a press mechanism and means for moving the table relatively to the other element.

Glass furnace. JOHN R. SCOHY. U. S. 1,347,181, July 20, 1920. A glass furnace having floaters and pockets formed in vicinity of and in advance to the outer end of the floaters for collecting scum held back by the floaters.

Glass molding machine. HENRY O. BISBING. U. S. 1,347,202, July 20, 1920. The combination of a molten glass reservoir, a discharge passageway for such reservoir, a chain-like series of glass receptacles adapted to be brought underneath such discharge passageway, and inclosure for the run-way of such chain-like series of glass receptacles and means for directing a hot blast through the roof of such inclosure against the discharging stream of molten glass.

Apparatus for testing lenses. FRANK TWYMAN. U. S. 1,347,133, July 20, 1920. An apparatus for testing a lens comprising a plane parallel glass plate partially silvered and adapted to reflect part of a beam of light and to transmit a part, two mirrors adapted to reflect the light back to the plate and mounted so that their distances from the plate can be varied, a carriage adapted to adjustably receive the lens to be tested and maintain the same in the path of light to and from one of the mirrors, means for removing the lens on the carriage both along and at right angles to its optical axis and means for turning the carriage about an axis at right angles to the end optical axis of the lens.

Apparatus for drawing glass cylinders. LAWRENCE EDWIN STEWART. U. S. 1,347,131, July 20, 1920. The combination with hoisting means, a fan and an electric motor for the fan, of an electric circuit including the motor, a rheostat operable automatically by the hoisting means, a manually operable rheostat, the rheostats being included in series in the motor circuit, a switch for excluding a portion of the resistance elements of the rheostats from the motor circuit.

Glass forming machine. RICHARD LA FRANCE. U. S. 1,348,365, August 3, 1920. The combination with a finishing mould, of a holding device to engage an article in the mould and hold it during the opening of the mould, a piston motor and means operated and controlled thereby to move the holding device laterally to a position over the article during a portion of the piston stroke and downward into engagement with the article during another portion of the stroke.

Imitation-beveled-glass panel. JOHN A. McAVOY. U. S. 1,345,792, July 6, 1920. This covers a glass panel having for simulating a bevel, a groove parallel to the margin and endless within the face of the panel, the groove being only to sufficient depth to cause refraction of light at the lines which it occupies.

Means for making sheet-glass. MICHAEL J. OWENS. U. S. 1,345,629, July 6, 1920. The combination with means for drawing a sheet of glass, of a bending roll over which the glass is drawn, and a flattening device moving over the surface of the glass in a direction lengthwise thereof.

Making sheet-glass. MICHAEL J. OWENS. U. S. 1,345,628, July 6, 1920. The combination with means for drawing a sheet of glass, of a bending roll over which the glass is drawn, and a flattening device moving transversely over the surface of the glass after it passes beyond the bending roll.

The method, which consists in continuously drawing a sheet of glass from a pool of molten glass over a support, cooling the sheet before it reaches the support and thereby causing a surface glaze to form thereon which will not

be marred by its contact with the support, and sliding a flattening device over the surface beyond the support, thereby flattening the sheet.

Sand-drying plant. HENRY W. NAGLE. U. S. 1,346,238, July 13, 1920. A sand plant comprising a sand bin having an opening through which the sand is adapted to flow by gravity, a gate for controlling the opening, spaced heating elements between and over which the sand is adapted to pass after leaving the bin, each of the elements having portions having different inclinations, the inclinations being steepest where the sand first flows and is wettest, and less steep at the points to which it passes after being partially dried, an inclined screen for shifting the sand as it leaves the heating elements, and a chute and hopper for receiving the shifted sand.

Lens-grinding machine. EDGAR D. TILLYER AND LUCIAN W. BUGBEE. U. S. 1,347,766, July 27, 1920. A lens-grinding machine, including a frame, a rotating table bearing an annular grinding tool, the tool having a main spherical transverse curve and a supplemental transverse portion of different curve, a main drive gear carried by the frame, a plurality of spindles having pinions at their upper ends to mesh with the drive gear, and a plurality of lenses at their lower ends for engagement with the tool, whereby a pair of surfaces of different fuel will be formed on each of the lenses, and means for independently shifting the spindles to move their pinions out of the mesh with the main drive gear.
C. M. SAEGER.

Whiteware and Porcelain

Casting of porcelain. ANON. *Sprechsaal*, 53, 228 (1920).—In many cases it was found impossible to get rid of bubbles in casting porcelain unless the mold was first coated with slip before casting. Bubbles are due to inferior kaolin, wet molds, wrong water content, which should be neither too low or too high, and to improper pouring. Air bubbles may be removed from the slip by jarring the mold after casting or by stirring violently with a stick before all of the slip has been added. In pouring, the slip should be thrown against one side of the mold, thus preventing the entrapping of air. All plaster should be screened in making a mold, thus preventing lumps of unequal density.
H. G. SCHURECHT.

Porcelain doll heads. ANON. *Sprechsaal*, 53, 306 (1920).—Doll heads are cast, and when leather hard the eyes and mouth are cut out. A suitable body consists of 30 kaolin, 40 feldspar and 30 flint. This body is ground 90 hrs. with 2 per cent soda. If it is desired to glaze the heads, the body should only be ground 24 hrs., as longer grinding tends to craze the glaze. A glaze maturing at cones 8-9 consists of 28.76 feldspar, 9.52 dolomite, 10.35 whiting, 17.23 calcined kaolin and 34.14 quartz.
H. G. SCHURECHT.

PATENTS

Process and apparatus for molding clay products. DAVIS BROWN. U. S. 1,347,484, July 20, 1920. Apparatus for forming clay articles, comprising a mould receiving table, a power actuated cylinder in alignment with the table, jolt ramming mechanism having a vertically removable table normally at rest and in alignment with the mould receiving table, a hopper carried by the vertically reciprocating table and spaced therefrom, and automatic means to actuate the power cylinder and jolt ramming mechanism, whereby an empty mould applied to the mould receiving table will be forced under the hopper and thereupon subjected to jolt ramming action with the hopper to fill the mould, the action of the cylinder forcing the mould into position, being automatically retracted to receive the second empty mould, and the successive action of the cylinder removing the filled mould and positioning the second empty mould under the hopper.

Clay turning machine. LILLIAN L. RANDALL AND EDWARD A. FRIES. U. S. 1,348,580, August 3, 1920. A machine for turning plastic material comprising a tube adapted to have an elongate rod of plastic material fed therethrough, the tube being arranged closely to confine the rod of plastic material throughout the entire length of the rod, means that the forward end of the tube yielding to grip the rod throughout an extensive area, a tool in operative relationship to the end of the rod projecting from the forward end of the tube, and means for producing relative angular motion between the tube and the tool to cause the tool to operate upon the rod. The method of forming tubular articles from plastic material comprising rotating a blank of the plastic material, boring the blank along its axis of rotation, and turning the exterior of the blank while the boring tool is extended thereinto, the plastic blank being supported by the boring tool while being turned.

C. M. SAEGER.

Enamels

Enamels for sheet iron and steel. J. B. SHAW. Bur. of Standards, *Tech. Paper 165*.—This is a general treatise dealing with the technology of enameling sheet iron and steel. It has been prepared to answer the demand for a treatise dealing with the technology of the manufacture of vitreous enamels for these metals. This subject is not treated adequately in any existing publication. In collecting data for this paper an effort was made to obtain reliable and authentic information wherever available and to correlate it in such a manner as to shed some light on the problems encountered by enamellers. The treatise is a compilation of data dealing with the subject of enameling from various publications, from the notebook of the author, from the files of the Bureau, and from the experience of men engaged in the enameling industry in this country. Among the subjects dealt with in connection with the properties and preparation of steel for enameling are physical and chemical requirements, sand blasting, treatment preliminary to pickling and methods of

piekling. A chapter is devoted to the properties of the raw materials used in compounding enamels. The relations between chemical composition and physical properties of enamels are discussed fully. The procedure used in the preparation, applying and firing enamels are described in detail. The calculation of enamel formulas is fully explained and examples are given. The physical properties of enamels are dealt with in some detail and resistance of enamels to chemical action is fully discussed. R. N. BOORMAN.

Composition of blue enamel for cast iron. *Schnurpfel's Review for Glass Works*, 4, 613.—Feldspar 34, borax 21, soda ash 13, fluorspar $5\frac{1}{2}$, saltpetre 2, cobalt oxide $1\frac{1}{2}$. R. J. MONTGOMERY.

PATENTS

Coating apparatus. LAWRENCE R. DAVIS. U. S. 1,347,256, July 20, 1920. A combination with a spraying device, of a series of carriers for the articles to be coated, means for successfully moving the carriers into register with the spraying device, and controlling means for the spraying device adapted to automatically shut off the spray prior to the movement of a carrier into register therewith, with controlling means comprising a drive shaft for the carrier-operating means, a sleeve valve carried by the drive shaft at one end thereof, a casing for the valve, and a conduit affording communications between the valve and the spraying device.

Method and apparatus for coating or enameling metal. JOHN S. JOBE. U. S. 1,348,361, August 3, 1920. In the art of coating metal castings, the method which consists in supporting the casting to be coated in an inclined position with one of its surfaces exposed to coating operations, coating such surface, and then turning the casting into a reverse inclined position to expose its other surface without removing it from its support and coating the other surface, substantially as described.

Crane hinge for muffle furnace doors. GEORGE W. LINDSAY. U. S. 1,346,903, July 20, 1920. A mounting for muffle furnace doors comprising in combination with the furnace and its door, a crane hingedly mounted at one end on the furnace and having a swivel connection at its other end with the door of the crane portion of the swivel connection being positioned above the door, whereby the door may be swung out beneath the crane.

C. M. SAEGER.

Brick and Tile

Non-plastic material for brick. ANON. *Tonind. Ztg.*, 44, 689 (1920).—In most cases sand is used to reduce the shrinkage of clay brick when this is necessary. Ground brick bats make an excellent substitute for sand, since the brick do not crack as easily and dry faster than those in which sand is used. When ground brick bats are used they should be burned hard as soft

burned bats may cause scumming. In a few cases cinders are used as a non-plastic but it is necessary to select those free from soluble salts.

H. G. SCHURECHT.

Loam press brick. WALIGORSKI AND CARRIERE. *Le Ciment*, 25, 54 (1920) *Tonind. Ztg.*, 44, 644 (1920).—Brick were made with a pressure of 200–400 kg. per sq. cm. The loam used contained 5–10 per cent clay and it was found that those containing the most clay were the strongest. The brick should have a crushing strength of at least 50 kg. per sq. cm. Since the brick are readily disintegrated with water, investigations are now under way to develop a covering which will protect the brick from the rain.

H. G. SCHURECHT.

Brick sand. H. SACHSE. *Tonind. Ztg.*, 44, 718 (1920).—In *Tonind. Ztg.*, 55, 529, the author calculates the amt. of sand present in brick clays from their chem. analyses which is incorrect. A more accurate way is by rational and mechanical analysis. In comparing both methods the following results were obtained for free silica:

Calculated from

| | | | | | | | |
|----------------|-------|-------|-------|-------|-------|-------|-------|
| chem. analysis | 32.80 | 35.80 | 41.00 | 43.20 | 49.90 | 57.80 | 72.18 |
|----------------|-------|-------|-------|-------|-------|-------|-------|

From mechanical

and rational

| | | | | | | | |
|---------------|-------|-------|-------|-------|-------|--------------|--------------|
| analysis..... | 39.72 | 40.96 | 42.64 | 50.39 | 58.80 | 50.64 quartz | 67.03 quartz |
| | | | | | | and 19.37 | and 0.45 |
| | | | | | | mineral | mineral |
| | | | | | | particles. | particles. |

It is important to know whether the silica is present as fine or free silica or combined silica, since it is necessary to burn clays containing fine or combined silica to a higher temp. than those containing coarse or free silica.

H. G. SCHURECHT.

Street paving with sand lime brick. H. JOLIG. *Tonind. Ztg.*, 44, 703 (1920).—The fact that some sand lime brick have a crushing strength of 320 kg. per sq. cm. led to experiments in using sand lime brick for pavements and sidewalks. After 10 yrs. service the streets made of sand lime brick were in excellent condition, whereas roads made of natural rock and ballast failed in this period. This pavement was situated near the front and received severe traffic. During this period, 10–20 mm. was worn from the surface of the brick and it was predicted that this road would stand 10–15 yrs. more service. The brick are 65 × 140 × 290 mm. and are made of clean, fine sand and 11 per cent lime. These pavements are supported on either side by cement curbing, the pavement forming an arch between the curbings. The spaces between the brick are about 5 mm. which are filled up with fine sand. For sidewalks they are much more attractive than clay brick and do not become slippery in wet weather.

H. G. SCHURECHT.

PATENTS

Brick machine. HAROLD H. GOE. U. S. 1,344,880, June 29, 1920. This machine is for making taper brick, the combinations of an upper die having an inclined surface to produce the taper, a lower die, a die box and yielding means in the die construction and arranged to effect, prior to compression, a graded distribution of the material in the die box substantially in accordance with the taper of the brick to be formed and to assume, during compression, a position which does not interfere with the formation of the brick.

C. M. SAEGER.

Cement and Lime

Quicklime and milk of lime. B. KOSMANN. *Tonind. Ztg.*, **44**, 555 (1920).—Lime upon slaking continues to take up H_2O until some of it contains 8 mols. of water. Lime tetrahydrate is probably the hydrate which contains all chemically combined H_2O , whereas those containing more than 4 mols. are combined with water partly mechanically. Lime tetrahydrate is known as the hydrogel of lime and is colloidal in nature, being slippery and remaining in suspension in water for long periods. The sp. gr. of some of the hydrates are as follows: $Ca(OH)_2 = 2.236$, $H_3Ca(OH)_5 = 1.345$, and $H_7Ca(OH)_9 = 1.198 - 1.224$.

H. G. SCHURECHT.

Cement substitutes. C. PLATZMANN. *Tonind. Ztg.*, **44**, 697-699 (1920).—The big demand for cement has led to the manuf. of many substitutes. Those known as "Vulkancement," "Montanzement" and "Refractory Cement" are unfit for building purposes. A new cement known as "Cementin" has been put on the market. The strength of this cement after storage for 28 days is only 58.1 kg. per sq. cm., whereas that of Portland cement is 345 kg. per sq. cm. "Silikalit," another cement substitute, was found to compare closely to Portland cement. This is supposed to be a ground hydraulic lime. Hydraulic lime may be produced by grinding lime with blast furnace slag or phonolite. The principal reactions are the formation of silicate which upon setting form a bond. It is suggested that volcanic slag be used together with cements thus decreasing the amt. of cement necessary.

H. G. SCHURECHT.

The effect of acids on concrete. ANON. *Sprechsaal*, **44**, 573 (1920).—It is repeatedly stated in literature that cements are resistant to dilute acids. It is well known that cements are not resistant to carbonic acid and for this reason must be protected with a covering of asphalt. W. Petry (*Der Bauingenieur* **I**, 12 (1920)) states that the action of those acids which form soluble salts with lime are more destructive to cements than those which form insoluble compounds with lime as sulphuric acid. Contrary to this statement it is known that sulphuric acid is harmful to cements. P. also states that acid solutions containing less than $1/10$ acid are harmless which must also be denied.

H. G. SCHURECHT.

Destruction of cement pipes and mortar. A. SPLITTERGERBER. *Wasser und Gas*, 17, (1920); *Tonind. Ztg.*, 44, 719-20 (1920).—Among destructive agencies are acids and sulphur. These may be present in the soil, in ground waters, in the air and from materials used in building construction. To prevent destruction, the cement should be made water-tight, which may be done by the addition of substances which combine chemically with the cement, or by the application of a protective coating such as asphalt, or brick masonry. The article contains a bibliography of literature on this subject.

H. G. SCHURECHT.

The setting of calcium sulphate cements. C. L. HADDON. *Jour. Soc. Chem. Ind.*, 39, 165T.—Plaster of Paris forms a weak cement because of the large excess of water, and hence the smaller percentage of cement. The crystals are also much finer grained than with any other calcium sulphate cement. Neat calcium sulphate cement must be kept damp to ensure complete hydration. This is not necessary if a sulphate solution (Cu, Fe^{II}, Fe^{III}, ammonium, Al) is added; a 3-5 per cent solution mixed to a thick paste gives the best cement. Contrary to Rohland's theory, sulphates exert a marked accelerating effect on setting. With 5 per cent or stronger sulphate solutions a peculiar drop occurs in the tensile strength after the first day and the cement subsequently becomes stronger on drying.

R. N. BOORMAN.

Measurement of plasticity of mortars and plasters. WARREN E. EMLEY. Bur. of Standards, *Tech. Paper* 169.—An instrument has been devised whereby the work done in spreading a plaster on a wall can be measured. A sample of the plaster is molded into cylindrical form on a porous plate. It is then pressed with a continuous screw motion against a stationary conical disk. The forces transmitted through the sample to this disk are measured. The porous base-plate acts as the undercoat on a wall to suck the water out of the sample; the disk acts as a trowel to spread the sample over the base-plate. The instrument enables one to measure the rate of drying of the plaster, the force required to spread it, and the thinness to which it can be spread. A proper correlation of these three factors leads to a definite expression of the degree of plasticity of the material.

R. N. BOORMAN.

Recommended specifications for quicklime and hydrated lime for use in the cooking of rags for the manufacture of paper. Bur. of Standards, *Circ.* 96.—This is the first of a series of specifications for the lime used in various chemical industries. The new specification is based on a draft originally prepared at the Bureau of Standards. To assist in perfecting the specification, the Bureau of Standards called an interdepartmental conference of representatives of several bureaus most concerned. As revised, the specification has the unanimous approval of those concerned, including the National Lime Association and the Technical Association of the Pulp and

Paper Industry. In addition to giving the percentage maxima or minima of the significant constituents, detailed regulations are given for the packing and marking, and careful directions for the analytical methods used.

R. N. BOORMAN.

PATENTS

Plaster board. LEWIS E. ARMSTRONG AND HUGH BOWYER BROCKENBROUGH. U. S. 1,347,487, July 27, 1920. A plaster board comprising a body of plastic material, a sheet of fibrous material covering one face of the body and having a marginal portion engaging an edge of the body and adapted to be folded over upon the opposite face of the body, a sheet of fibrous material covering the opposite face of the body and in lapping engagement with the folded-over marginal portion of the first-mentioned sheet, the latter having portions thereof removed to permit the material of the body to pass through the underlapping marginal portion and to adhere to the folded-over marginal portion.

Art of making plaster board. MORGAN K. ARMSTRONG. U. S. 1,348,387, August 3, 1920. The process consists of advancing a bottom sheet of fibrous material, of superposing thereon a plastic mixture to form the body of the board, of confining the plastic mix in such a manner on the bottom sheet as to leave marginal parts of the sheet exposed at each side of the same beyond the intended width of the plaster board, of superposing a narrower top sheet of fibrous material on the plastic mix and at the same time spreading the plastic mix evenly over the bottom sheet to the intended thickness of the board, of turning over the projecting marginal parts of the bottom sheet to overlap the marginal parts of the top sheet, first spreading on the projecting parts a small amount of plaster so that the small amount is turned over with the projecting marginal parts of the bottom sheet upon the marginal parts of the top sheet, the turning-over process being continued so as to depress the marginal parts of the top sheet, and of ironing out and smoothing the board to thoroughly adhere the top and bottom sheets to the body.

C. M. SAEGER.

ACTIVITIES OF THE SOCIETY

New Members Received during July

Resident Associate

- Carhart, C. C.**, Sheffield, Iowa, President, Sheffield Brick and Tile Co.
Deppeler, J. H., Jersey City, N. J., Chief Engineer, Thermit Dept., Metal & Thermit Corporation.
Francais, Paul P., Frankfort, Ind., Supt., Ingram-Richardson Mfg. Co.
Hansen, J. E., Mellon Institute, Pittsburgh, Pa.
Hoyler, Fritz W., Perth Amboy, N. J., Works Manager, Roessler & Hasslach Chemical Co.
Kawai, Kozo, 747 East 36th St., Chicago, Ill.
Kleinfeldt, Henry F., 220 Broadway, New York City, Secretary, Abbé Engineering Co.
Littleton, J. T., Jr., Corning, N. Y., Corning Glass Works.
Offill, Paul M., 901 Oliver Bldg., Pittsburgh, Pa., District Manager, Laclede-Christy Clay Products Co.
Rhodes, George E., 1609 N. Webster St., Kokomo, Ind., Vice-President, and General Manager, Kokomo Sanitary Pottery Co.

Foreign Associate

- Brown, Thomas G.**, St. Laurent, Quebec, Canada, Works Manager, Gurney Foundry Co.

New Members Received during August

Resident Associate

- Colburn, Ed. D.**, 2801 Hereford St., St. Louis, Mo., Superintendent, Blackmer & Post Pipe Company.
Gonder, Lawton G., Zanesville, Ohio, Research Department, American Encaustic Tiling Company.
Gregori, Andrew, 3308 W. Lexington St., Chicago, Ill., Kiln Burner, Midland Terra Cotta Company.
Hammer, John M., Box 555, Pittsburgh, Pa., Managing Editor, "China, Glass and Lamps."
Kingsbury, Percy C., 145 West 45th St., New York City, Chief Engineer, General Ceramics Company.
Knowles, W. V., Peoples Gas Bldg., Chicago, Ill., District Manager and Technical Representative, Titanium Alloy Manufacturing Company and Buckman & Pritchard, Inc.

Rawson, Cummins, Des Moines, Iowa, Iowa Pipe and Tile Company.

Snider, Paul C., 37 Southard Ave., Zanesville, Ohio, Research Department, American Encaustic Tiling Company.

Twells, Robert, Jr., 417 Union St., Schenectady, N. Y., General Electric Company.

Wood, C. P., Stock Exchange Bldg., Philadelphia, Pa., Manager, Philadelphia Office, Lockwood, Greene & Company.

Foreign Associate

Bush, H. T., 59 Yonge St., Toronto, Ont., Canada, President, Universal Silicates, Ltd.

Havas, A. B., 57 Rohrbacher St., Heidelberg, Germany, Consulting Chemist, Roessler & Hasslacher Chemical Company.

Munroe, L. J., 912 Colborne St., London, Ont., Canada, Chief, Enamel Department, McClary Manufacturing Company.

Corporation

"The Glass Worker," Box 555, Pittsburgh, Pa.

Meeting of the St. Louis Section

On Friday, August 6th, the St. Louis Section held a business meeting at Forest Park Highlands with twenty-four members and guests present.

Through the courtesy of Mr. George Thomas, of the Highlands Fire Clay Co., the Section was given the use of the swimming pool and most of those present enjoyed a swim before dinner. Following the business meeting, Mr. F. C. Baker gave a talk on pyrometry which caused an interesting discussion. At the request of Mr. George Thomas the question of the application of rotary filters to filtering washed clays was discussed, the discussion being led by Dr. A. Malinovszky. Mr. A. B. Christopher concluded the program by giving a brief talk on the scumming of fire brick.

Judging by the number of new men attending the meeting and by the interest and enthusiasm shown, the Section should have some very interesting meetings during the coming year.

GAIL R. TRUMAN, *Secretary*.

Ceramic Day at the Chemical Exposition

Friday, September 24th, has been designated as Ceramic Day at the Sixth National Exposition of Chemical Industries at the Grand Central Palace, New York. The program for this day is in charge of the American Ceramic Society. Papers will be given at the afternoon session by representatives of the industrial divisions of the Society. Moving pictures dealing with various ceramic industries will be given in the evening. The meetings will be held in the conference room on the fourth floor.

The Society has been assigned Booth 750 on the fourth floor near the elevator. In this booth the activities of the Society will be demonstrated by charts and by display of the publications of the Society. The Assistant Secretary will be in charge each day to take registrations, to enroll new members, and to explain the work of the Society to visitors. The various ceramic schools will also display illustrations of their work and equipment.

Necrology

Mr. Henry Schmidt died on August 26th following an operation for acute appendicitis.

Mr. Schmidt entered the employ of the Roessler and Hasslacher Chemical Company in May, 1905. After having passed satisfactorily through various positions he was transferred to the ceramic department in June, 1911. By close attention to his work in this department and by pursuing courses in salesmanship and business management, he fitted himself for advancement to the sales department, which he entered on January 1, 1916. He continued in this department up to the time of his death.

Mr. Schmidt was well known to the ceramic industry of this country and was a member of the American Ceramic Society for many years. On account of his pleasing personality, he was liked by all with whom he came in contact; and on account of the integrity of his character, he was highly respected by all with whom he had business dealings. He was more than a salesman; he was a real man who happened to be selling ceramic materials. His sudden death will be greatly lamented by all his friends and acquaintances. Mr. Schmidt leaves a wife and two children.

Report of Summer Meeting, 1920

A total slightly in excess of the century mark established, we believe, a new record for attendance at the Summer Meeting this year, which was held in Chicago, August 16th, 17th and 18th.

The generous contributions toward the entertainment fund by many of the local manufacturers, the splendid coöperation and team work on part of the Local Committee, and the cordial reception tendered by all the plants visited combined to make the meeting highly successful from every standpoint.

The members assembled at the Hotel La Salle at 12.30 P. M., Monday, and proceeded by special elevated train to the plant of The Bach Brick Co., where the use of the Penfield setter and combination fuel oil-steam system of burning proved highly interesting. The same train conveyed the party from here to the plant of the Northwestern Terra Cotta Co. Here the Dressler tunnel kiln, completed and ready for operation, and the new humidity dryers, successfully operating, held the special attention of the party for the remainder of the day.

In the evening, through the generous aid of the local manufacturers, a complimentary dinner was tendered the visiting members at the Hotel La Salle.

The dinner was followed by a short business session, after which "Dean" Gates became master of ceremonies and conducted that office in his usual interesting style. R. H. Minton, President, who had just returned from an extensive trip abroad, gave us a highly interesting talk on industrial and political conditions in Germany. Mr. Minton's talk was followed by one or two other short informal speeches, after which the guests were entertained by two vaudeville stunts. Features of added interest to this event were the presentation of a souvenir terra cotta ash tray to each guest by the American Terra Cotta Co., and of a beautiful ceramic lamp by the Claycraft Shops, to be presented by lot. The Chairman takes this opportunity to announce publicly, and calls on President Minton for confirmation of the fact, that it was by no pre-arranged scheme that the lamp fell to "Dean" Gates, to the great satisfaction of everyone present.

On Tuesday morning, the party visited the plants of the Lindsay Light Co., manufacturers of gas mantles, and were conveyed via taxicabs from there to the Union Station, where they boarded a special car to the plant of the Coonley Manufacturing Co., makers of enameled cooking utensils. Both of these plants proved highly novel and interesting. Leaving here at noon, again by special car, the party was conveyed to the huge plant of the Western Electric Co., where a most excellent complimentary luncheon was served, and cordial reception tendered. The entire afternoon was spent witnessing the various operations employed in the manufacture of equipment used in the telephone and telegraph industry.

The final day of the meeting started with a pleasant ride on a special train of the North Shore Electric Line, through the beautiful north shore suburbs of Chicago, past Fort Sheridan and Great Lakes Naval Training Station to Waukegan and North Chicago. The first plant visited here was that of the American Steel and Wire Co., where the rolling and drawing of six-inch billets into wire, and the subsequent manufacture of springs, fencing, etc., was watched with great interest.

After leaving this plant the visitors were again tendered a splendid luncheon by the Chicago Hardware Foundry Co., manufacturers of porcelain enameled ware, and found great pleasure in witnessing the various operations employed in this plant.

The return to Chicago was made by special train, several of the members stopping off at Ravinia Park where their attention was divided between the grand opera rendition of "Faust," and a "new" line of stories by Ray Stull.

The sustained interest on part of the visiting members and cheerful adherence to the program as mapped out, made the work of the Local Committee a real pleasure.

F. B. ORTMAN, *Chairman.*

JOURNAL

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Vol. 3

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EDITORIAL

SCIENTIFIC EXPERTS AND THE GOVERNMENT SERVICE

There has come to the attention of the office of the Director of the Bureau of Standards, a very general and wholesome protest against Dr. A. V. Bleining leaving the government employ. This protest is generally so worded as to very much encourage the belief that the ceramics industry is inspired by a common soul that has an interest not only in the industry but in humanity.

One common point is made that Dr. Bleining has been working for years, very largely at government expense and with facilities furnished by the government, to help the entire industry of the country, and it is asserted that his services are needed by the entire ceramics industry. Consequently, it is unfair that any single firm take his entire services. It is the general feeling that some means should be found to maintain such experts where public rather than selfish interest is at stake.

Since this attitude of the ceramics manufacturers is diametrically opposed to the view expressed by a number of speakers and writers recently, it seems worth while to point out that in a broad way the stability of the government is involved in this particular question or in such questions as this incident raises.

It has been said that it is the function of the government to look after the welfare of its people; to protect the weak, and to guide the people as a whole.

In order that the Government may best serve the individuals in our democracy it is obvious that this can be most efficiently accomplished through the government's contact with the large organized units which have interests in common. In some phases our separate states represent interests common to large groups; similarly our cities represent certain interests of groups. In quite another way railroad transportation, meat packing, engineering societies, philanthropic societies, labor organizations, etc., all represent common interests of one kind or another. It always follows sooner or later that the common interests of groups conflict with the common interests of other groups, and it follows further that sooner or later it is necessary for the government to adjust differences that exist in these groups. If the government is to stand, it can only do so so long as it has an intelligent appreciation of the differences of the conflicting interests of major importance. Every technical as well as every legal, political, and economic organization of the country should see to it that the government has on its staff men who are in a position to understand and to assist. When this has finally been accomplished, all the big industries of our country and the large organizations generally, will be in a mood to proclaim the worthwhileness of a central government with ideals and courage to act.

After all, it is not surprising that the ceramics industry which involves the oldest of human arts, should have arrived at a mature philosophy such as its leaders have recently expressed.

ORIGINAL PAPERS AND DISCUSSIONS

CERTAIN RELATIONS BETWEEN CHEMICAL COMPOSITION AND REFRACTIVITY IN OPTICAL GLASSES^{1,2}

BY FRED. E. WRIGHT

At the beginning of the war one of the serious problems which confronted the makers of optical glass in this country was the preparation of suitable "batches" for the types of optical glass required in military optical instruments. Before 1914 practically all of the raw optical glass used by American manufacturers was imported from Europe and little was known in this country of the processes of optical glass-making. This information had to be obtained quickly and put at once into practice if our field forces were to be adequately equipped with optical instruments for observational and measuring purposes.

In May, 1917, shortly after a group of men from the Geophysical Laboratory had been assigned, at the request of the Government, to the plant of the Bausch and Lomb Optical Company, Rochester, N. Y., to aid in the production of optical glass,

¹ Received Feb. 27, 1920.

² In the preparation of this paper a somewhat uncommon experiment was tried, namely, to present the major part of the subject-matter in graphical form. The written text is accordingly condensed and is an outline sketch rather than a comprehensive statement. The diagrams constitute the essential part of the paper and on them the emphasis has been placed. It is possible that this method of presentation is unsatisfactory; but by its adoption the length of the paper was greatly reduced and the methods actually used for attacking and developing a subject of this nature were thereby followed. The data (in particular the chemical data) which enter into the problem are in general not of a high order of precision and are therefore well adapted for study by graphical methods, especially as the practical problems are problems of interpolation and adjustment of different factors.

it was the writer's good fortune to deduce from the chemical and optical data then available certain relations which enabled us to write down the batch composition of any member of the flint series of glasses; also by graphical interpolation to cover most of the types of optical glass, including the barium crowns, borosilicate crowns, ordinary crowns, and the barium flints. This deduction had an important psychological effect because it rendered us independent of secret batches which had been obtained at great expense by empirical methods and were closely guarded; the new methods of attack gave us control over the whole series of batches. This one factor established, at the outset, our standing in the factory as practical glass-makers, and, as a result, secured for us hearty coöperation at a time when it was much needed.

The methods of computation are here presented in the incomplete form in which they were left at the close of the war. There is still much to be learned and much detailed information to be gathered before a comprehensive treatment of the subject can be attempted; but with the data now available it is a simple matter to reproduce any of the standard types of glass or of types intermediate between those listed in the glass-makers' catalogs.

Refractivity Relations in Optical Glasses

A fundamental requirement of optical glass is transparency and freedom from color; this means the absence of an absorption band in the visible spectrum; and this in turn sets a definite limitation to the possible variations in refractivity and greatly restricts the general character of the dispersion relations. With change in color (wave length of light) the refractive indices of optical glass change in the manner illustrated in figures 1a and 1b in which the refractive indices¹ of different kinds of optical glass are plotted for different wave lengths of light extending from the ultra-violet through the visible spectrum into the infra-red. The change in refractive index of a substance with change in wave length of light is called its optical dispersion. In an optical

¹ Measured by H. Rubens and T. H. Simon on a series of Schott glasses *Ann. d. Phys. u. Chem. N. F.*, **53**, 555 (1894).

glass the difference between the refractive indices for two given wave lengths of light is called its partial dispersion for that interval. Different types of optical glass are characterized not only by a difference in refringence for the same color, but also by different dispersion relations in the visible spectrum. These are of great importance to the lens designer.

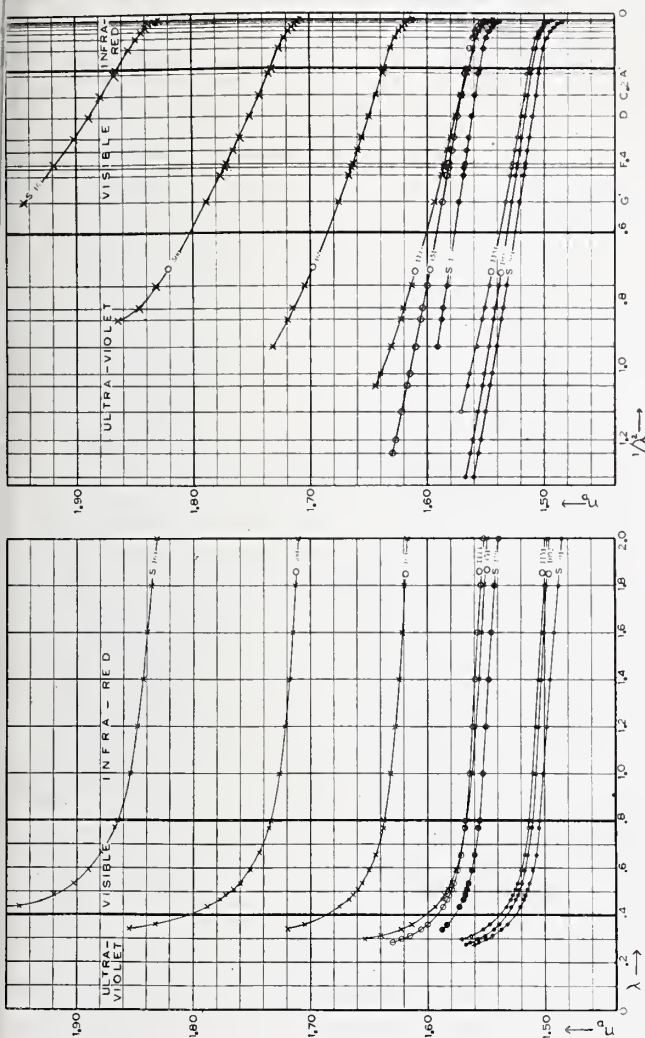


FIG. 1.—In Fig. 1a the refractive indices for different wave lengths in the infra-red, visible, and ultra-violet, as measured by H. Rubens and H. T. Simon on a series of Schott glasses, are plotted as ordinates against the wave lengths as abscissae.

In Fig. 1b the abscissae scale has been changed from the direct wave scale (λ) of Fig. 1a to that of the square of the frequency ($1/\lambda^2$). The refractive indices are the ordinates. By this method of plotting, the inflection point of the dispersion curves in the visible spectrum is clearly shown as a result of the absorption band in the ultra-violet and also in the infra-red.

In accordance with the practice inaugurated by Abbe, the characteristics of an optical glass are stated by listing the following constants:

(a) Its refractive index for a definite color, generally that of the mean of the two sodium *D*-lines of average wave length, 0.5893 μ (microns or thousandths of a millimeter).

(b) The difference between the refractive indices for certain spectral colors (partial dispersions); the colors or spectral lines commonly selected are:

| Spectral line | A' | C | D | F | G' |
|---|--------------------|------------------|-----------------|------------------|------------------|
| Color..... | Deep red | Red | Yellow | Blue | Violet |
| Wave length in microns (μ).... | 0.7682 | 0.6563 | 0.5893 | 0.4861 | 0.4341 |
| Source of light.... | Potassium flame | Hydrogen tube | Sodium flame | Hydrogen tube | Hydrogen tube |

The refractive indices corresponding to these wave lengths are expressed: $n_{A'}$, n_C , n_D , n_F , $n_{G'}$. The partial dispersions commonly listed are the mean dispersion $n_F - n_C$ and the partial dispersions $n_D - n_{A'}$, $n_F - n_D$, $n_{G'} - n_F$.

(c) The ratios of the last three dispersions to the mean dispersion; these are called the partial dispersion ratios.

(d) The expression $\nu = \frac{n_D - 1}{n_F - n_C}$ which is, in effect, the excess refractivity of the glass for the *D*-line measured in terms of the mean dispersion; it has been called the optical constringence; its reciprocal is by definition the dispersive power of the glass.

These constants suffice to characterize an optical glass so well that the optical designer is able to select from a given list those particular glasses which best answer his purpose. It can be proved that in a telescope objective consisting of a positive and a negative element, the degree of achromatism attainable in the image (freedom from spurious color, secondary spectrum) depends directly on the degree of similarity of the spectra of the two glasses (expressed by the difference between the partial dispersion ratios and inversely on the difference between the ν -values).

In the old types of glasses (ordinary crowns and ordinary flints) the dispersion increases with the refractive index (figures

1 and 2), but the dispersion in the blue end of the spectrum increases more rapidly than that in the red, and the spectra of

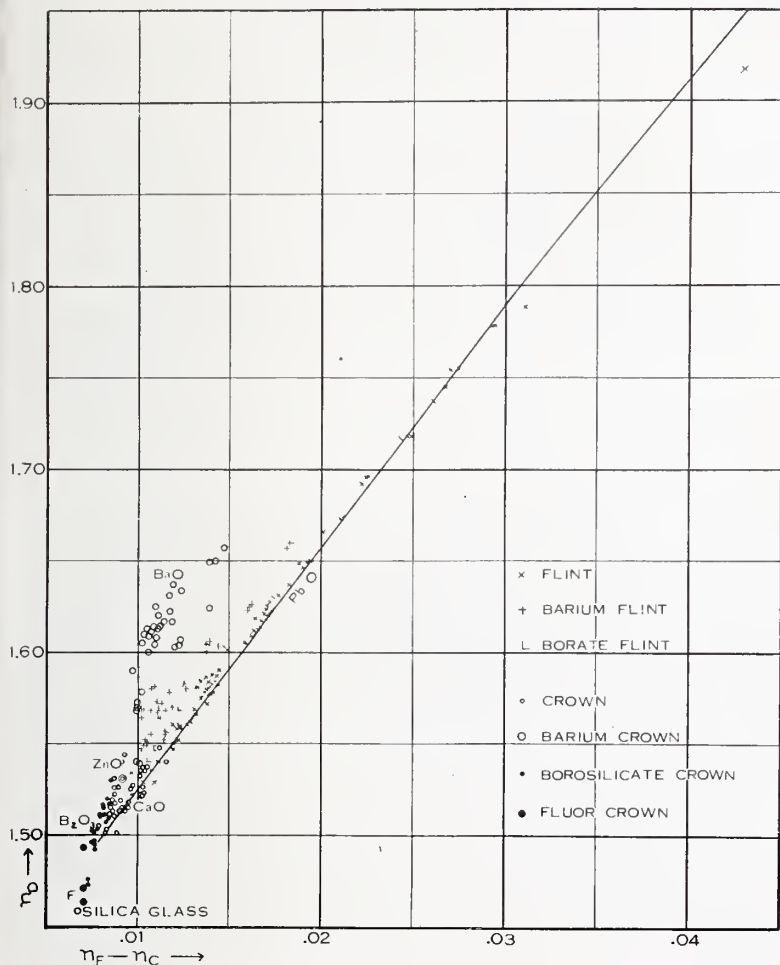


FIG. 2.—In this figure the mean dispersions of a series of glasses are plotted as ordinates, the refractive indices as abscissae. The old series of ordinary crown and flint glasses fall on a practically straight line.

different glasses are so dissimilar (irrationality of dispersions) that only a fair correction for achromatism can be attained.

The introduction of new types of glasses by Abbe and Schott enables the lens designer to produce much better lens systems than was formerly possible.

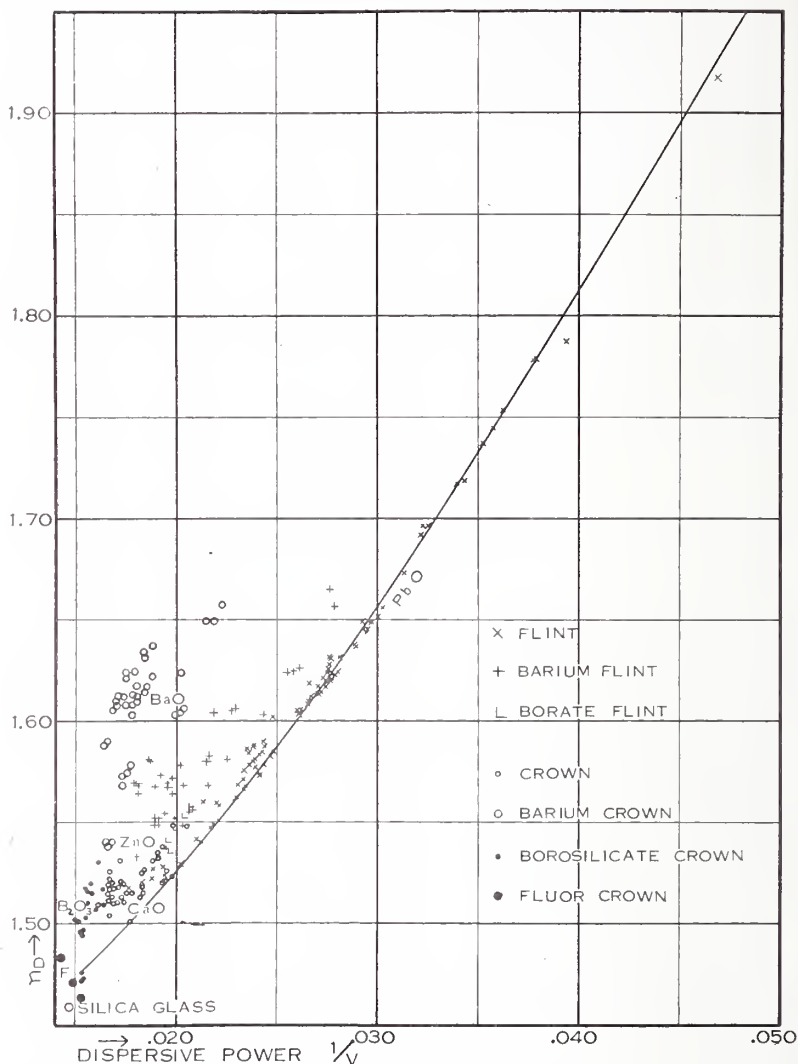


FIG. 3.—In this diagram the dispersive powers of a series of optical glasses are plotted against their refractive indices, n_D .

The different aspects of the refractivity relations of optical glasses are presented in figures 2 to 7. These will now be considered in some detail.

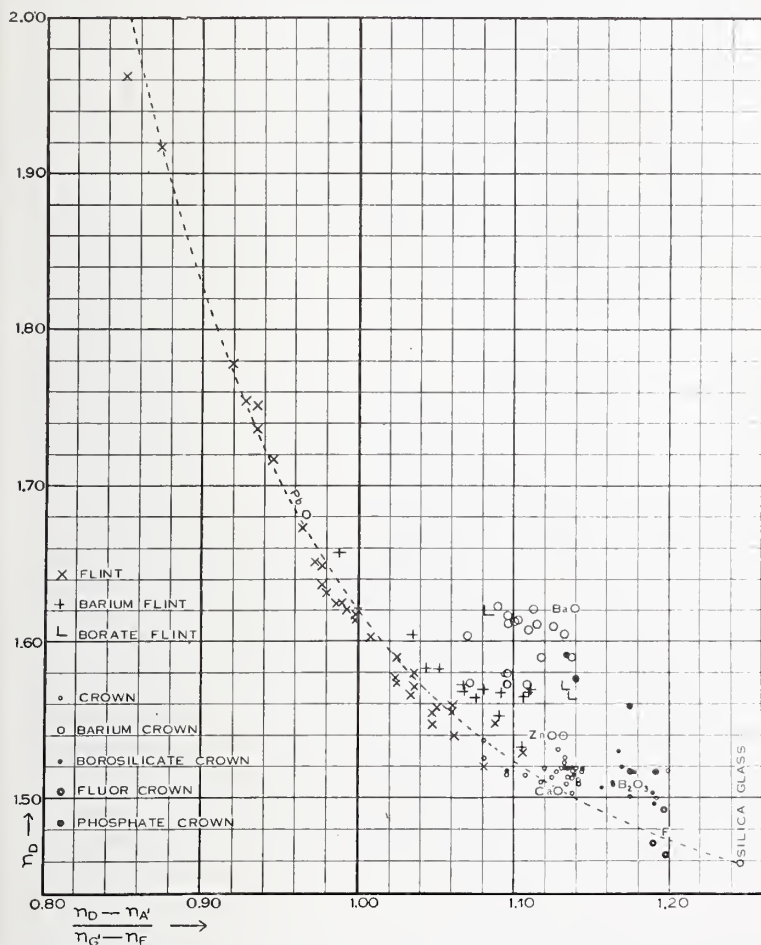


FIG. 4.—In this figure the ratio $\frac{n_D - n_{A'}}{n_{G'} - n_F}$, which expresses in effect the length of the red end of the spectrum relative to that of the blue end, is plotted against the refractive index n_D for a series of different types of silicate optical glasses.

It has long been known that if the mean dispersions of ordinary crown glasses and of flint glasses be plotted against refractive index, the points fall approximately on a straight line (figure 2). In other words, in these older types of glass the mean dispersion increases directly with the refractive index. It was to overcome this limitation that Harcourt, and later Abbe and Schott, investigated the changes produced in optical glasses by radical changes in the chemical composition. They found that boron and barium are especially valuable in this connection; in figure 2 the relations between refractive index and mean dispersion in the new Schott and Parra-Mantois glasses are also given and show how far some of these depart from the straight line of the old flints and crowns.

If the dispersive powers ($1/\nu$ as defined above) of the Schott glasses are plotted against the refractive index (figure 3), the old type glasses fall on a slightly curved line; the fields of the new types of glasses are clearly differentiated on the diagram. This is also true when the ν -values of the glasses are plotted against refractive index, although in this diagram the curve of the old type glasses is much more curved.

In figure 4 the ratios of the partial dispersions in the red ($n_D - n_A'$) and blue ($n_G - n_F$) ends of the spectrum (relative length of the red to that of the blue) are plotted against the refractive index, n_D . This diagram illustrates probably better than the others the refractivity-dispersion relations; in it the fields of the different glass types are well marked. Thus in the fluor-crown glasses the length of the red end of the spectrum exceeds that of the blue end relatively more than in any other glass type; the borosilicate crowns follow next in order; then the ordinary crowns, the barium crowns, the barium flints, and finally the flints in which the relative dispersion of the blue ($n_G - n_F$) exceeds that of the red ($n_D - n_A'$).

It is possible from figure 4 to select glasses differing appreciably in absolute refringence and at the same time to state their relative dispersions in the blue and red parts of the spectrum. Chemical analyses of many of the glasses plotted on this diagram are listed in table 3; by combining graphically the information presented in figure 4 and table 3, it is possible to deduce by interpolation

the approximate chemical compositions of glasses intermediate in optical properties between those which are plotted. The methods for accomplishing this are described in a later paragraph.

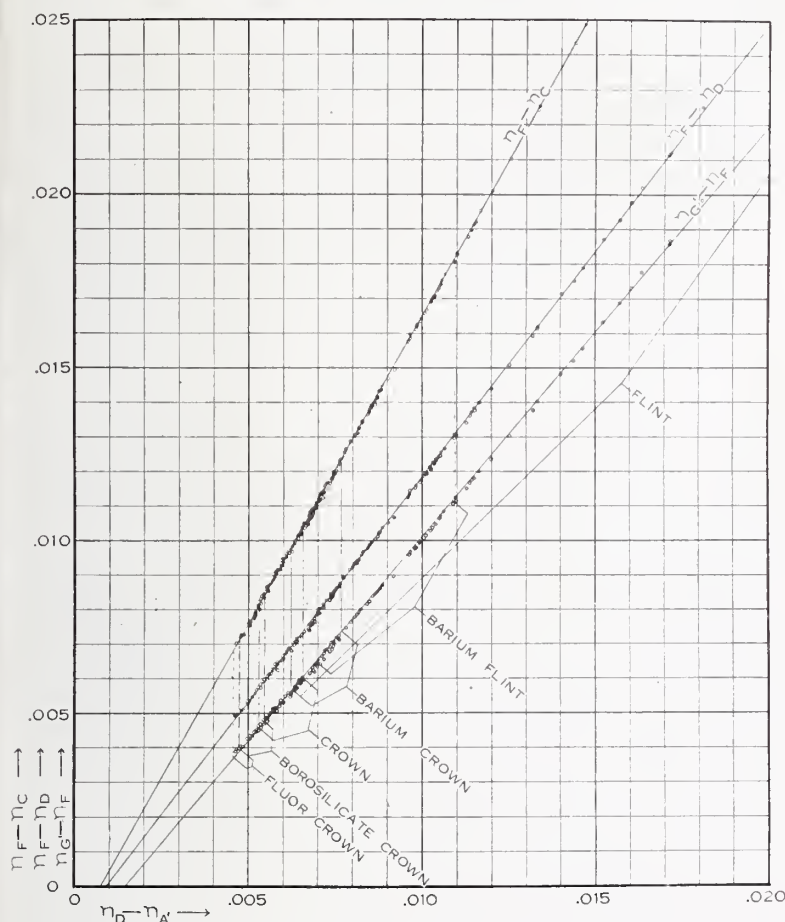


FIG. 5.—In this figure the partial dispersions, $n_F - n_C$, $n_F - n_D$, and $n_G - n_F$, of all silicate optical glasses listed by Parra-Mantois and by Schott, are plotted as ordinates against the partial dispersion $n_D - n_{A'}$. The result in each case is an approximately straight line.

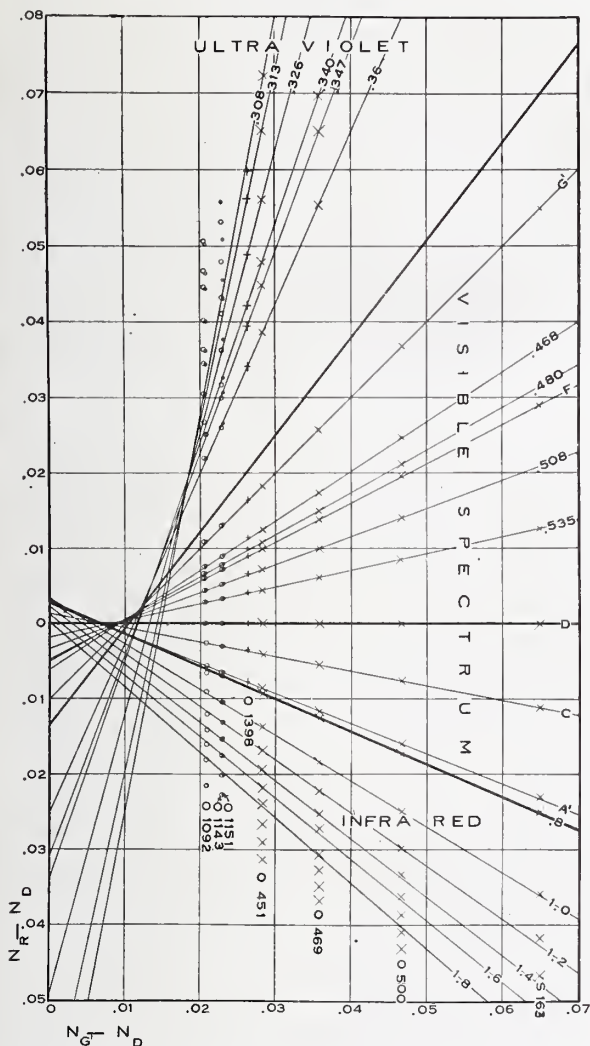
Figure 4 shows, moreover, the extent to which the glass-maker has succeeded in changing the refractivities of optical glasses.

The diagram includes the borate and phosphate glasses, in addition to the silicate glasses.

If now we consider only the partial dispersions and plot as in figure 5 the partial dispersion $n_F - n_C$, $n_F - n_D$, and $n_G - n_F$ against $n_D - n_A$, for a series of silicate glasses, the result in each case is a straight line; in figure 5 the partial dispersions of all the silicate glasses listed by Schott of Jena, and Parra-Mantois of Paris (about 289 different glasses in all) are included except those of the densest flint S 386 of Schott. This is a remarkable result and states that any partial dispersion of a glass bears a linear relation to any other partial dispersion; the degree of departure from this relation does not exceed one or two units in the fourth decimal place for the glasses plotted. Except for the dense barium crown glasses the distance of the points from the straight line is commonly only a few units in the fifth decimal place.

This fact, that in a series of optical glasses the partial dispersions are related by linear functions, proves that once a partial dispersion is given, the entire dispersion curve is fixed irrespective of the type of optical glass. This means that within the limits to which this statement holds, namely, about one unit in the fourth decimal place, if any partial dispersion is given, all other dispersions follow automatically; in other words, a change in dispersion at one part of the dispersion curve carries with it definite changes in the curve throughout the visible spectrum. Thus a series of standard dispersion curves can be set up independent of the absolute refractive index. This signifies that if, for any optical glass, two refractive indices be given, its dispersion curve can be written down directly; that in case two optical glasses of very different indices are found to have the same actual dispersion for one part of the spectrum, their dispersion curves are identical to one or two units in the fourth decimal place throughout the visible spectrum. If, for example, the refractive index, n_D , and the ν -value of an optical glass be given, its mean dispersion $n_F - n_C$ can be computed from the equation $n_F - n_C = (n_D - 1)/\nu$; its partial dispersions $n_D - n_A$, $n_F - n_D$, and $n_G - n_F$ can then be read off directly from figure 5 with a fair degree of accuracy, sufficient, at least, to give an adequate idea of the run of dispersion in the glass.

From these relations it is possible to build up dispersion formulas¹ containing two or three constants which represent the data in the visible spectrum with a high degree of exactness.



which is distant from an absorption band. With the approach to an absorption band the dispersion curve departs from its even course and is no longer comparable with the dispersion curves of other glasses. This is well shown in figure 6 in which the measurements of H. Rubens in the infra-red and H. T. Simon¹ in the visible and ultra-violet in a series of optical glasses are plotted in terms of the partial dispersions. The different types of glasses are named on the diagram. The similarity in the course of the partial dispersions is well shown by two glasses in the list, namely, a crown of high dispersion *O* 1151, and of refractive index $n_D = 1.52002$, and a barium crown, *O* 1143, of refractive index $n_D = 1.57422$. In table 1 the partial dispersions $n_F - n_D$ are listed.

TABLE 1.—In this table the partial dispersions, $n_F - n_D$ of a crown of high dispersion, *O* 1151, and a barium crown, *O* 1143, are given for a series of wave lengths, r , extending from the infra-red at $2\ \mu$ to the ultra-violet at $0.2980\ \mu$.

| Wave length in μ r | <i>O</i> 1151 $n_F - n_D$ | <i>O</i> 1143 $n_F - n_D$ | Wave length in μ r | <i>O</i> 1151 $n_F - n_D$ | <i>O</i> 1143 $n_F - n_D$ |
|--------------------------------|------------------------------|------------------------------|--------------------------------|------------------------------|------------------------------|
| 2.0 | —0.02272 | —0.02272 | 0.4861 | 0.00713 | 0.00704 |
| 1.8 | — .02012 | — .02012 | .4800 | .00780 | .00766 |
| 1.6 | — .01762 | — .01772 | .4678 | .00901 | .00884 |
| 1.4 | — .01522 | — .01542 | .4340 | .01310 | .01288 |
| 1.2 | — .01312 | — .01312 | .3610 | .02664 | .02500 |
| 1.0 | — .01042 | — .01312 | .3466 | .03066 | .02977 |
| 0.8 | — .00692 | — .00692 | .3403 | .03260 | .03161 |
| 0.7682 | — .00634 | — .00640 | .3261 | .03768 | .03623 |
| .6563 | — .00290 | — .00302 | .3133 | .04305 | .04103 |
| .5892 | .00000 | .00000 | .3081 | .04556 | .04103 |
| .5349 | .00325 | .00324 | .2980 | .05091 | .04791 |
| .5086 | .00523 | .00516 | .. | ... | ... |

In this table it is evident that the partial dispersions of the two glasses run along fairly well together from the infra-red at $2\ \mu$ to the violet of the visible spectrum. From here on into the ultra-violet the crown with high dispersion, which contains 13.3 per cent of lead oxide, approaches an absorption band and its partial dispersions rise accordingly.

The different effects of lead, barium, boron and other glass-making oxides are more clearly shown in the infra-red and ultra-violet than in the visible spectrum. The maximal departure

¹ *Ann. Phys. u. Chem. N. F.*, 53, 555 (1894).

from normal dispersion curves in the visible spectrum caused by the presence of large amounts of barium is two units in the fourth decimal place.

In the series of flint glasses an increase in lead oxide content raises the refractive index and causes the absorption band in the ultra-violet to shift toward the visible spectrum. This is clearly shown by the flint glasses plotted in figure 6, namely, *O* 451 ($n_D = 1.57524$), *O* 469 ($n_D = 1.64985$), *O* 500 ($n_D = 1.75130$), *S* 163 ($n_D = 1.88995$). Simon was unable, because of the presence of this absorption band, to measure the refractive indices of the light flint *O* 451 beyond the wave length 0.2980μ , of the medium flint *O* 469 beyond 0.3261μ , of the very dense flint *O* 500 beyond 0.3403μ , and of the densest flint *S* 163 beyond 0.4340μ . Further evidence of the shift of the absorption band with increase in lead oxide content has been obtained by the direct measurement of the transparency of the flint glasses to ultra-violet light. Data on the transmission of plates of flint and other optical glasses in the ultra-violet are given in the catalog of optical glasses issued by Chance Bros. The results of their measurements on the flint glasses are reproduced in table 2 in which the limit of trans-

TABLE 2.—Transparency of flint glasses in the ultra-violet

| Type No. | Name | n_D | ν | Approximate percentage PbO | Wave lengths (μ) for transmission | |
|----------|-------------------|--------|-------|----------------------------|---|-----|
| | | | | | 50% | 10% |
| 7863 | Extra light flint | 1.5290 | 51.6 | 18 | 330 | 321 |
| 6953 | Light flint | 1.5412 | 47.6 | 23.5 | 316 | 313 |
| 572 | Dense flint | 1.6182 | 36.4 | 45 | 337 | 330 |
| 360 | Dense flint | 1.6225 | 36.0 | 46 | 338 | 332 |
| 337 | Very dense flint | 1.6469 | 33.7 | 51 | 347 | 341 |
| 4480 | Very dense flint | 1.7401 | 28.3 | 66 | 370 | 360 |

parency of a glass plate 1 centimeter thick is indicated by the wave lengths at which the percentage transmissions are 50 and 10, respectively.

With the exception of the first member of this series, which may contain an appreciable amount of zinc oxide that may affect the transparency in the ultra-violet, the absorption band is seen to shift continuously with increase in lead content toward the longer wave lengths and the visible spectrum.

The yellow color of the very dense flints has been ascribed to

the influence of this absorption band in reducing the intensity of the violet and blue of the visible spectrum; other factors, however, such as the presence, as impurities, of small amounts of iron oxide and possibly also of lead dioxide or other oxide of lead may have a pronounced influence on the color. Very dense flint glasses made of materials of high chemical purity and under conditions of thorough oxidation are noticeably less colored than glasses of the same composition whose batches and heat treatment have not been scrutinized carefully.

There are other approximately straight-line dispersion relations within the visible spectrum which may be noted because on them certain empirical dispersion formulas are based. Thus if the refractive indices be plotted as ordinates against the squares of the frequency ($1/\lambda^2$) as abscissae the course of the dispersion of an optical glass is represented by a curve which departs only slightly from a straight line (figure 1b); these departures are commonly less than one unit in the third decimal place.¹ A dispersion formula built up on this relation is the two-constant formula of Cauchy, namely,

$$n = A + B/\lambda^2$$

The formula may also be written

$$n - 1 = A' + B/\lambda^2$$

In view of the fact that the range of refractive indices in optical glasses over the visible spectrum is relatively limited, any approximately straight line relation between refractive index and a function of the wave length, such as expressed by the foregoing Cauchy formula, becomes an hyperbola if the reciprocal be taken of the refractive index or the excess refractivity; but the portion of the curve covered by the visible spectrum is so short that, even in this case, the departure of the hyperbola from a straight line is not great and the dispersion relations are still fairly well represented. Thus the new formula recently suggested by

Nutting² is the Cauchy formula in which $\frac{1}{n-1}$ is written for $n-1$;

¹ See Sellmeier, *Ann. d. Phys. u. Chem.*, **143**, 272 (1871); also Pulfrich, *Ann. d. Phys. u. Chem.*, **45**, 648 (1892); and Hovestadt, *Jenaer Glas*, pp. 46-48, Jena, 1900.

² *Revisita d'Ottica e Meccanica di Precisione*, **1**, 54-57 (1919).

Nutting's formula represents the dispersions in certain cases better than the Cauchy formula, whereas in other glasses the Cauchy formula is the better. It would lead too far, in the present paper, to present data of computation on a series of Gifford glasses which bear out this statement. The conclusion is, however, directly evident from a comparison of figures 7a and 7b in which for all silicate glasses of Schott the squares of the

frequency (τ/λ^2) are plotted as abscissae against $\frac{n-1}{n_{A'}-1}$ and

its reciprocal $\frac{n_{A'}-1}{n-1}$ respectively, as ordinates. As a result of this

method of plotting, all dispersion curves pass through the unit ordinate for the A' -spectrum line; the dispersion curves radiate from this point as approximately straight lines, the departures from straight lines being greatest in the dense flints and also in the very light crowns and borosilicate crowns.¹

Another method of expressing the relations of the Nutting formula is to plot the frequency scale on the horizontal line at unit distance from the abscissa axis, to draw lines radiating from the origin through the points on the frequency scale and to find the intercepts of these lines with ordinates equal to the refractive indices.² The dispersion curves under these conditions are approximately straight lines.

These relations suffice to prove that in any dispersion formula (if carried only over the visible spectrum in a transparent colorless substance such as optical glass) which expresses the dispersion relations in approximately linear form, the reciprocals may be taken of the refractive index or any function of the same and the new dispersion curve thus obtained will again be approximately a straight line. In the ultra-violet and infra-red the relations may no longer obtain and inevitably break down as an absorption band is approached.

¹ Compare F. E. Wright, *Journ. Opt. Soc. America*, 4, 195-204 (1920).

² For a brief account of this method of plotting reciprocals see F. E. Wright, *Jour. Wash. Acad. Sci.*, 10, 185-188 (1920).

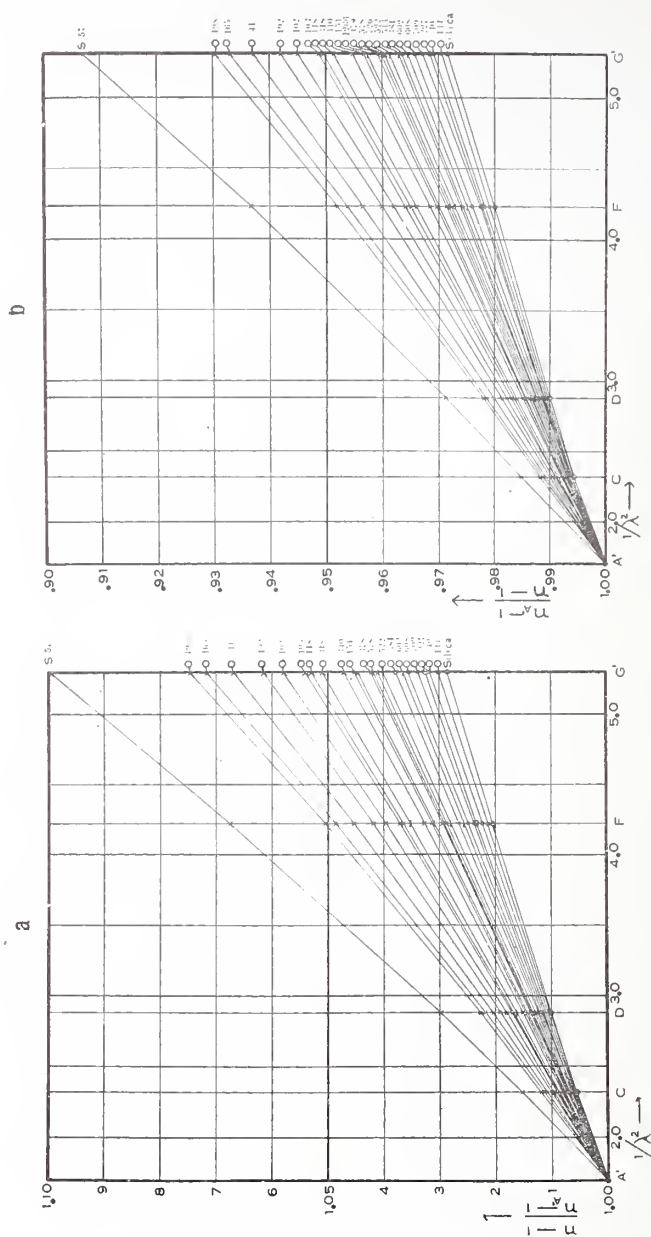


FIG. 7.—In Fig. 7a the ratios $(n_p - 1)/(n_d - 1)$ for a series of Schott glasses are plotted as ordinates against the squares of the frequency $(1/\lambda^2)$ as abscissae. In Fig. 7b the reciprocal ratios $\frac{n_p - 1}{n_d - 1}$ are plotted as ordinates against the same abscissae scale $(1/\lambda^2)$. The series of glasses represented in these figures are the same as those listed in Table 1 and include all types of silicate glasses. These figures demonstrate clearly the feasibility of substituting in the Cauchy dispersion formula $\frac{1}{n^2}$ for $n - 1$ and thus obtaining the Nutting formula.

In figure 7a the excess refractivity ($n-1$) for any wave length is expressed for each glass in terms of its excess refractivity for the A' wave length ($n_{A'}-1$). The curves of this figure demonstrate that with rise in refractive index the dispersion also rises, and in the flint series especially the dispersion increases relatively faster than the refractive index. This fact of increased rate of rise of dispersion with increase in absolute refringence is also clearly shown by a comparison of the dispersion relations in the flint series of glasses, after reduction for each glass of all its refractive indices in the ratio n/n_D or $n/n_{A'}$. This procedure reduces the refractive index of each glass for the D -line to unity and thus renders the relations directly comparable. On plotting the ratios n/n_D against λ or $1/\lambda^2$ we find that in spite of the reduction of all glasses to a common datum level of absolute refringence ($n_D = 1$), the higher the refringence in the flint glass series the greater the slope of the dispersion curve, thus proving the relatively greater dispersion of the heavy flint glasses.

The foregoing relations, together with other relations, such as are shown by graphical plots in which (a) $\frac{n_G - n_F}{n_F - n_D}$ is plotted against $\frac{n_D - n_{A'}}{n_F - n_D}$; (b) $\frac{n_r}{n_D}$ against the wave length, λ_r , directly; (c) n_r against λ_r ; (d) n_r against ν_r demonstrate that the actual shape of a dispersion curve in optical glasses can be changed only in a definite manner and that the departures from any one of the set of standard dispersion curves do not exceed two units in the fourth decimal place. The effort of the glass-maker is therefore necessarily directed toward the production of glasses of different refringences for the same general run of dispersions.

In the foregoing paragraphs the dispersion relations of optical glasses are presented on the diagrams in some detail and from different view points purposely, because they are of fundamental importance to the study of dispersion not only in optical glasses but also in other colorless substances. They indicate clearly the limits which the glass-maker has reached in his efforts to produce different types of optical glass and demonstrate that the paths which he may follow are narrowly prescribed.

Chemical Relations

The study of the refractivity relations in optical glasses as illustrated in the foregoing diagrams indicates that certain chemical oxides in combination with silica dominate certain fields. To determine these relations chemical analyses are essential; unfortunately the available analyses are not all of equal value. Table 3 contains the best chemical analyses⁴ at present known to

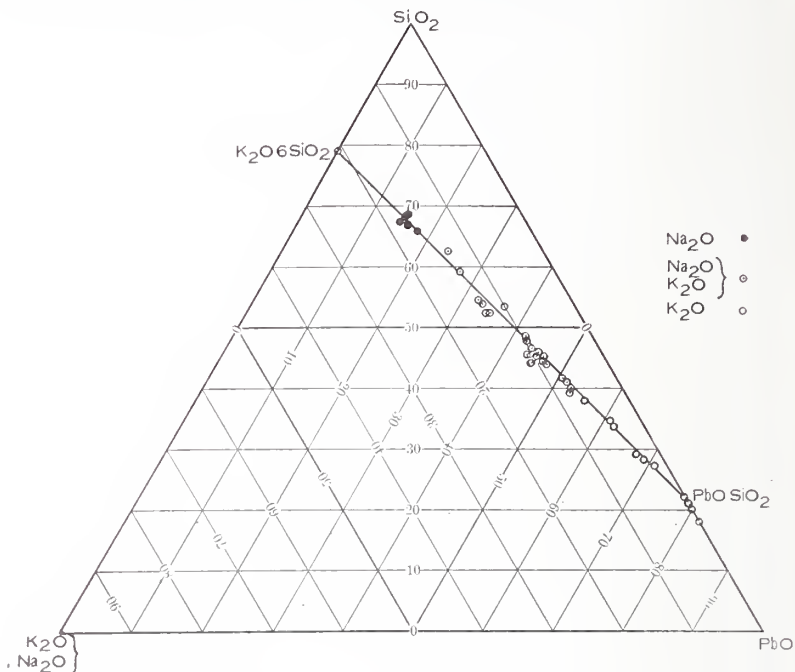


FIG. 8.—Triaxial diagram showing the weight percentage compositions of the potash flint and soda-potash flint glasses.

the writer.¹ Many of these "analyses" are synthetic compositions computed from the batch compositions; in the table the sum in each analysis of this type is either 100.0, or 99.9.

The simplest series of optical glasses is evidently the flint series and for this reason this series was studied first and certain com-

¹ See also list of analyses published by Williams and Rand. *THIS JOUR.*, 2, 434-441 (1919).

TABLE 3.—Synthetic and actual chemical analyses of optical glasses of different types. In this table and accompanying legend are listed the chemical composition, the refractive index n_D , the ν -value, the density d , and the partial dispersions ($P. D.$) of the several glasses so far as these have been determined. The abbreviation Zsch. refers to the list of chemical analyses published by E. Zschimmer in Doelter's *Handbuch der Mineralchemie*, Vol. I, pp. 869–889 (1914). The abbreviation (*W*) refers to the list of glass analyses published first by Winkelmann in the *Ann. d. Phys. u. Chem.*, 49, 401 (1893); 51, 697, 730 (1894); 61, 105 (1897); and later reproduced in Hovestadt's book on Jenaer Glas, Jena, 1900.

| No. | SiO ₂ | B ₂ O ₃ | Al ₂ O ₃ | As ₂ O ₃ | PbO | ZnO | CaO | BaO | K ₂ O | Na ₂ O | Total | n_D | ν | d |
|---------------------|------------------|-------------------------------|--------------------------------|--------------------------------|-----|------|-------|------|------------------|-------------------|-------|--------|-------|------|
| Ordinary Crowns | | | | | | | | | | | | | | |
| 1..... | 74.6 | ... | ... | 0.3 | ... | ... | 5.0 | ... | 11.0 | 9.0 | 100.0 | 1.5055 | 60.2 | 2.5 |
| 2..... | 72.26 | 0.03 | 0.08 | .. | ... | ... | 11.61 | ... | 0.20 | 13.81 | 98.50 | 1.5261 | 59.3 | .. |
| 3..... | 71.34 | ... | .09 | .90 | ... | ... | 12.51 | ... | .10 | 13.42 | 98.73 | 1.5250 | 59.1 | .. |
| 4..... | 70.6 | ... | .. | .3 | ... | ... | 11.0 | ... | 16.0 | 2.0 | 100.0 | 1.5179 | 60.2 | 2.49 |
| 5..... | 71.6 | ... | .. | .7 | ... | ... | 8.0 | 2.6 | 9.0 | 8.1 | 100.0 | 1.516 | 60.0 | .. |
| 6..... | 69.3 | ... | .3 | .3 | ... | ... | 10.3 | ... | 19.2 | 0.2 | 99.6 | 1.5176 | 60.1 | .. |
| Borosilicate Crowns | | | | | | | | | | | | | | |
| 7..... | 72.15 | 5.88 | 0.04 | 0.08 | ... | ... | 2.04 | ... | 13.85 | 5.16 | 99.74 | 1.5102 | 64.1 | 2.47 |
| 8..... | 70.4 | 7.5 | .. | .2 | ... | ... | 2.0 | ... | 14.5 | 5.3 | 100.0 | 1.5100 | 64.0 | 2.47 |
| 9..... | 70.0 | 8.0 | .. | .2 | ... | ... | 2.0 | ... | 14.5 | 5.3 | 100.0 | 1.5118 | 63.5 | 2.47 |
| 10..... | 70.0 | 8.3 | .. | .3 | ... | ... | 1.9 | ... | 12.0 | 7.4 | 100.0 | 1.511 | 64.1 | .. |
| 11..... | 68.2 | 10.0 | .. | .2 | ... | ... | 2.0 | ... | 9.5 | 10.0 | 100.0 | 1.5116 | 63.5 | 2.47 |
| 12..... | 72.0 | 12.0 | 5.0 | .. | ... | ... | ... | ... | ... | 11.0 | 100.0 | 1.4997 | 64.7 | 2.37 |
| 13..... | 71.0 | 14.0 | 5.0 | .. | ... | ... | ... | ... | ... | 10.0 | 100.0 | 1.4990 | 64.6 | 2.37 |
| 14..... | 71.23 | 8.20 | 1.47 | .. | ... | ... | 1.99 | ... | 12.58 | 3.63 | 99.48 | 1.5140 | 63.1 | ... |
| 15..... | 70.6 | 6.0 | 1.0 | .3 | ... | ... | ... | ... | 10.5 | 11.5 | 100.0 | 1.5069 | 62.3 | 2.48 |
| 16..... | 70.95 | 6.30 | 0.88 | .20 | ... | 1.46 | 0.17 | ... | 9.22 | 10.11 | 99.51 | 1.5079 | 62.1 | ... |
| 17..... | 69.58 | 9.91 | .04 | .09 | ... | ... | .07 | 2.54 | 8.37 | 8.44 | 99.54 | 1.5164 | 64.0 | ... |

Table 3 (continued)
Borosilicate Crowns (continued)

| No. | SiO ₂ | B ₂ O ₃ | Al ₂ O ₃ | As ₂ O ₃ | PbO | ZnO | CaO | BaO | K ₂ O | Na ₂ O | Total | <i>n_D</i> | <i>v</i> | <i>d</i> |
|---------------------|------------------|-------------------------------|--------------------------------|--------------------------------|------|-------|------|-------|------------------|-------------------|--------|----------------------|----------|----------|
| 18..... | 69.0 | 2.5 | .. | .4 | ... | ... | 8.0 | ... | 16.0 | 4.0 | 100.0 | 1.5168 | 60.9 | 2.49 |
| 19..... | 68.5 | 3.5 | .. | .3 | ... | 1.0 | ... | 9.7 | 5.0 | 12.0 | 100.0 | 1.5183 | 60.4 | 2.63 |
| 20..... | 68.1 | 3.5 | .. | .4 | ... | 7.0 | ... | ... | 16.0 | 5.0 | 100.0 | 1.5107 | 60.5 | 2.5 |
| 21..... | 67.73 | 9.98 | .06 | .. | ... | 1.78 | 0.05 | ... | 10.07 | 9.29 | 99.51 | 1.5142 | 64.0 | .. |
| 22..... | 65.6 | 4.5 | .. | .4 | ... | 11.5 | ... | ... | 3.5 | 14.5 | 100.0 | 1.5175 | 60.2 | 2.59 |
| 23..... | 65.5 | 2.5 | .. | .4 | ... | 2.0 | ... | 9.6 | 15.0 | 5.0 | 100.0 | 1.5170 | 60.4 | 2.49 |
| 24..... | 64.6 | 2.7 | .. | .4 | ... | 2.0 | ... | 10.2 | 15.0 | 5.0 | 100.0 | 1.5179 | 60.2 | 2.58 |
| 25..... | 53.5 | 20.0 | .. | .. | ... | ... | ... | ... | 6.5 | ... | 100.0 | 1.5159 | 53.6 | 2.6 |
| Zinc Silicate Crown | | | | | | | | | | | | | | |
| 26..... | 71.0 | ... | ... | ... | ... | 12.0 | ... | ... | ... | 17.0 | 100.0 | 1.5128 | 57.3 | 2.57 |
| Barium Crowns | | | | | | | | | | | | | | |
| 27..... | 59.5 | 3.0 | .. | 0.3 | ... | 5.0 | ... | 19.2 | 10.0 | 3.0 | 100.0 | 1.5408 | 59.8 | 2.73 |
| 28..... | 59.13 | 3.04 | 0.11 | .34 | ... | 5.00 | 0.13 | 19.25 | 9.70 | 3.16 | 99.88 | 1.5409 | 59.6 | .. |
| 29..... | 48.8 | 3.0 | .. | .4 | ... | 10.3 | ... | 29.0 | 7.5 | 1.0 | 100.0 | 1.5727 | 58.0 | .. |
| 30..... | 48.9 | 3.8 | 1.0 | .3 | ... | 8.9 | ... | 28.6 | 4.3 | 4.3 | 100.0 | 1.570 | 57.0 | .. |
| 31..... | 48.2 | 3.7 | 1.0 | .3 | ... | 8.8 | ... | 29.5 | 7.5 | 1.0 | 100.0 | 1.5724 | 57.6 | 3.21 |
| 32..... | 48.1 | 4.5 | .. | .4 | ... | 10.1 | ... | 28.3 | 7.5 | 1.0 | 100.0 | 1.5726 | 57.5 | 3.21 |
| 33..... | 47.8 | 4.5 | .. | .3 | ... | 10.3 | ... | 28.5 | 7.5 | 1.0 | 100.0 | 1.5742 | 57.2 | 3.21 |
| 34..... | 47.73 | 3.90 | 0.65 | .38 | ... | 8.61 | 0.15 | 29.88 | 7.16 | 1.14 | 99.84 | 1.5726 | 57.4 | .. |
| 35..... | 46.9 | 4.5 | .. | .5 | ... | 10.5 | ... | 29.0 | 7.5 | 1.0 | 99.9 | 1.5748 | 56.9 | 3.21 |
| 36..... | 48.8 | 3.0 | .. | .3 | 4.1 | 15.5 | ... | 21.0 | 6.5 | 0.8 | 100.0 | 1.5791 | 53.6 | 3.26 |
| 37..... | 45.02 | 4.50 | 0.09 | .06 | 4.70 | 15.53 | ... | 22.39 | 6.80 | .64 | 100.18 | 1.5795 | 53.8 | .. |
| 38..... | 39.6 | 6.0 | 2.5 | .5 | ... | 9.2 | ... | 42.1 | ... | ... | 100.0 | 1.6090 | 56.6 | 3.55 |
| 39..... | 40.17 | 5.96 | 2.79 | .03 | ... | 8.17 | 0.03 | 42.35 | 0.03 | 0.13 | 100.17 | 1.6095 | 56.8 | .. |

Table 3 (continued)
Barium Crowns (continued)

| No. | SiO ₂ | B ₂ O ₃ | Al ₂ O ₃ | As ₂ O ₃ | PbO | ZnO | CaO | BaO | K ₂ O | Na ₂ O | Total | <i>n_D</i> | <i>v</i> | <i>d</i> |
|---------|------------------|-------------------------------|--------------------------------|--------------------------------|-------|------|------|-------|------------------|-------------------|--------|----------------------|----------|----------|
| 40..... | 37.5 | 15.0 | 5.0 | 1.5 | ... | ... | ... | 41.0 | ... | ... | 100.0 | 1.5899 | 60.8 | 3.32 |
| 41..... | 38.66 | 13.36 | 5.11 | 0.37 | ... | ... | ... | 41.53 | 0.05 | 0.30 | 99.38 | 1.5904 | 61.3 | .. |
| 42..... | 37.3 | 6.0 | 2.0 | .. | ... | 10.8 | ... | 40.5 | ... | 3.2 | 99.8 | 1.6097 | 55.7 | .. |
| 43..... | 34.5 | 10.1 | 5.0 | .5 | ... | 7.8 | ... | 42.0 | ... | ... | 100.0 | 1.6088 | 57.0 | 3.53 |
| 44..... | 34.56 | 10.96 | 5.02 | .04 | ... | 1.14 | ... | 46.91 | 0.09 | 0.21 | 99.48 | 1.6091 | 58.8 | .. |
| 45..... | 31.0 | 12.0 | 8.0 | 1.0 | ... | ... | ... | 48.0 | ... | ... | 100.0 | 1.6098 | 58.8 | 3.54 |
| Flints | | | | | | | | | | | | | | |
| 46..... | 69.2 | ... | .. | 0.3 | 6.5 | ... | 4.0 | ... | 17.0 | 3.0 | 100.0 | 1.5151 | 56.6 | 2.55 |
| 47..... | 68.7 | ... | .. | .2 | 13.3 | 2.0 | ... | ... | ... | 15.7 | 100.0 | 1.5202 | 51.6 | 2.7 |
| 48..... | 68.2 | ... | .. | .2 | 13.1 | 2.0 | ... | ... | ... | 16.5 | 100.0 | 1.5219 | 51.5 | 2.7 |
| 49..... | 67.40 | ... | 1.72 | .14 | 10.71 | 3.85 | 0.39 | ... | 0.14 | 15.13 | 99.69 | 1.5221 | 52.2 | .. |
| 50..... | 66.8 | ... | 1.5 | .2 | 11.6 | 3.8 | ... | ... | ... | 16.0 | 100.0 | 1.5228 | 52.0 | 2.7 |
| 51..... | 65.9 | ... | 2.0 | .2 | 16.3 | ... | ... | ... | ... | 15.5 | 99.9 | 1.5230 | 50.8 | 2.70 |
| 52..... | 62.6 | ... | .. | .3 | 24.1 | ... | ... | ... | 8.5 | 4.5 | 100.0 | 1.5414 | 46.9 | 2.87 |
| 53..... | 59.3 | ... | .. | .2 | 27.5 | ... | ... | ... | 8.0 | 5.0 | 100.0 | 1.5537 | 45.0 | 2.9 |
| 54..... | 54.75 | 0.45 | 0.04 | .06 | 29.30 | 0.96 | 0.05 | 1.64 | 7.99 | 4.31 | 99.97 | 1.5711 | 43.0 | .. |
| 55..... | 54.31 | 1.5 | .. | .2 | 33.0 | ... | ... | ... | 8.0 | 3.0 | 100.0 | 1.5710 | 43.0 | .. |
| 56..... | 53.7 | ... | .. | .3 | 36.6 | ... | ... | ... | 8.3 | 1.0 | 100.0 | 1.5752 | 41.0 | 3.22 |
| 57..... | 52.53 | 0.30 | 0.01 | .13 | 34.42 | 0.03 | 0.04 | ... | 8.21 | 3.78 | 99.72 | 1.5802 | 41.0 | .. |
| 58..... | 52.7 | ... | .. | .4 | 35.0 | ... | ... | ... | 5.5 | 6.3 | 100.0 | 1.580 | 41.1 | .. |
| 59..... | 48.7 | ... | .. | .3 | 42.0 | ... | ... | ... | 5.0 | 4.0 | 100.0 | 1.6054 | 37.9 | 3.5 |
| 60..... | 47.9 | ... | .. | 0.3 | 42.4 | ... | ... | ... | 5.1 | 4.3 | 100.0 | 1.605 | 37.6 | .. |
| 61..... | 46.6 | ... | .. | .3 | 43.8 | ... | ... | ... | 7.8 | 1.5 | 100.0 | 1.6137 | 36.9 | 3.58 |
| 62..... | 46.12 | ... | 0.06 | .35 | 45.13 | ... | 0.07 | ... | 6.78 | 1.72 | 100.38 | 1.6163 | 36.6 | .. |

Table 3 (continued)
Flints (continued)

| No. | SiO ₂ | B ₂ O ₃ | Al ₂ O ₃ | As ₂ O ₃ | PbO | ZnO | CaO | BaO | K ₂ O | Na ₂ O | Total | nD | ν | d |
|---------|------------------|-------------------------------|--------------------------------|--------------------------------|-------|-----|------|-----|------------------|-------------------|--------|--------|-------|------|
| 63..... | 46.32 | ... | .02 | .. | 45.03 | ... | .25 | ... | 5.63 | 2.48 | 99.82 | 1.6162 | 36.6 | .. |
| 64..... | 45.4 | ... | .. | .3 | 45.1 | ... | ... | ... | 7.7 | 1.5 | 100.0 | 1.6243 | 35.9 | 3.68 |
| 65..... | 45.2 | ... | .. | .2 | 46.0 | ... | ... | ... | 7.5 | 1.0 | 100.0 | 1.6153 | 36.7 | 3.58 |
| 66..... | 44.1 | ... | .. | .. | 44.7 | ... | ... | ... | 9.8 | 1.2 | 99.8 | 1.6188 | 36.2 | 3.6 |
| 67..... | 47.6 | ... | .. | .2 | 46.7 | ... | ... | ... | 5.0 | 0.5 | 100.0 | 1.6129 | 36.9 | 3.58 |
| 68..... | 45.64 | ... | 0.03 | .22 | 43.45 | ... | 0.05 | ... | 8.66 | 1.77 | 99.82 | 1.6137 | 36.9 | .. |
| 69..... | 45.2 | ... | .5 | .2 | 46.4 | ... | ... | ... | 7.5 | 0.2 | 100.0 | 1.6123 | 37.0 | 3.58 |
| 70..... | 43.9 | ... | .. | .2 | 47.3 | ... | ... | ... | 8.0 | .5 | 100.0 | 1.6130 | 37.0 | 3.58 |
| 71..... | 44.6 | ... | .. | .3 | 46.6 | ... | ... | ... | 8.0 | .5 | 100.0 | 1.6207 | 36.1 | 3.63 |
| 72..... | 41.7 | ... | .. | .3 | 50.5 | ... | ... | ... | 7.0 | .5 | 100.0 | 1.6485 | 33.8 | 3.87 |
| 73..... | 41.7 | ... | .. | .3 | 50.5 | ... | ... | ... | 4.0 | 3.5 | 100.0 | 1.640 | 34.6 | .. |
| 74..... | 41.0 | ... | .. | .2 | 51.7 | ... | ... | ... | 7.0 | ... | 100.0 | 1.6450 | 34.1 | 3.88 |
| 75..... | 40.99 | ... | 0.04 | .22 | 51.13 | ... | 0.13 | ... | 6.93 | 0.61 | 100.15 | 1.6485 | 33.8 | .. |
| 76..... | 40.0 | ... | .. | .3 | 52.6 | ... | ... | ... | 6.5 | .5 | 100.0 | 1.6500 | 33.6 | 3.87 |
| 77..... | 39.2 | ... | .. | .3 | 51.0 | ... | ... | 2.0 | 5.0 | 2.5 | 100.0 | 1.6657 | 32.9 | 4.1 |
| 78..... | 38.0 | ... | .. | .2 | 56.8 | ... | ... | ... | 5.0 | ... | 100.0 | 1.6801 | 31.7 | 4.1 |
| 79..... | 34.7 | ... | .. | .3 | 61.0 | ... | ... | ... | 2.5 | 1.5 | 100.0 | 1.7172 | 29.5 | 4.49 |
| 80..... | 33.7 | ... | .. | .3 | 62.0 | ... | ... | ... | 4.0 | ... | 100.0 | 1.7174 | 29.5 | 4.49 |
| 81..... | 29.3 | ... | .. | .2 | 67.5 | ... | ... | ... | 3.0 | ... | 100.0 | 1.7510 | 27.6 | 4.73 |
| 82..... | 28.4 | ... | .. | .1 | 69.0 | ... | ... | ... | 2.5 | ... | 100.0 | 1.7541 | 27.5 | 4.78 |
| 83..... | 27.3 | ... | .. | .1 | 71.0 | ... | ... | ... | 1.5 | ... | 99.9 | 1.7782 | 26.5 | 4.99 |
| 84..... | 22.0 | ... | .. | .. | 78.0 | ... | ... | ... | ... | ... | 100.0 | 1.8904 | 22.3 | 5.83 |
| 85..... | 21.0 | ... | .. | .. | 79.0 | ... | ... | ... | ... | ... | 100.0 | 1.9068 | 21.6 | .. |
| 86..... | 20.0 | ... | .. | .. | 80.0 | ... | ... | ... | ... | ... | 100.0 | 1.9053 | 21.7 | 5.94 |
| 87..... | 18.0 | ... | .. | 0.1 | 82.0 | ... | ... | ... | ... | ... | 100.1 | 1.9626 | 19.7 | 6.33 |

Table 3 (continued)

| No. | SiO ₂ | B ₂ O ₃ | Al ₂ O ₃ | As ₂ O ₃ | PbO | ZnO | CaO | BaO | K ₂ O | Na ₂ O | Total | <i>n_D</i> | <i>v</i> | <i>d</i> |
|--------------------|------------------|-------------------------------|--------------------------------|--------------------------------|-------|------|-----|-------|------------------|-------------------|--------|----------------------|----------|----------|
| Borosilicate Flint | | | | | | | | | | | | | | |
| 88..... | 29.0 | 29.0 | 10.0 | .. | 30.0 | ... | ... | ... | 0.5 | 1.5 | 100.0 | 1.5676 | 46.7 | 2.97 |
| Barium Flint | | | | | | | | | | | | | | |
| 89..... | 56.2 | ... | .. | 0.3 | 7.0 | 9.0 | ... | 15.0 | 11.0 | 1.5 | 100.0 | 1.5500 | 53.3 | 3.0 |
| 90..... | 55.9 | ... | .. | .3 | 17.3 | ... | ... | 11.5 | 13.0 | 2.0 | 100.0 | 1.5560 | 48.6 | 3.03 |
| 91..... | 53.5 | ... | .. | .3 | 11.0 | 10.0 | ... | 14.2 | 9.5 | 1.5 | 100.0 | 1.5630 | 50.8 | 3.11 |
| 92..... | 51.6 | ... | .. | .3 | 11.0 | 12.0 | ... | 14.0 | 9.5 | 1.5 | 99.9 | 1.5637 | 50.6 | 3.11 |
| 93..... | 51.7 | ... | .. | .3 | 10.0 | 7.0 | ... | 20.0 | 9.5 | 1.5 | 100.0 | 1.5718 | 50.4 | 3.19 |
| 94..... | 50.2 | ... | .. | .4 | 10.3 | 10.6 | ... | 17.7 | 9.5 | 1.3 | 100.0 | 1.5745 | 50.2 | 3.2 |
| 95..... | 51.2 | ... | .. | .3 | 4.0 | 14.0 | ... | 20.0 | 5.0 | 5.5 | 100.0 | 1.5692 | 52.9 | 3.12 |
| 96..... | 50.2 | ... | .. | .5 | 18.5 | 8.2 | ... | 13.1 | 8.5 | 1.0 | 100.0 | 1.5832 | 46.3 | 3.29 |
| 97..... | 49.80 | ... | 0.05 | .01 | 18.74 | 8.03 | ... | 13.36 | 8.20 | 1.24 | 100.03 | 1.5832 | 46.3 | .. |
| 98..... | 49.1 | ... | .. | .5 | 19.3 | 8.5 | ... | 13.0 | 8.5 | 1.0 | 100.0 | 1.5822 | 46.3 | 3.29 |
| 99..... | 45.2 | ... | .. | .4 | 22.2 | 8.3 | ... | 16.0 | 7.8 | ... | 100.0 | 1.6042 | 43.9 | 3.50 |
| 100..... | 45.2 | ... | .. | .4 | 22.8 | 8.2 | ... | 15.5 | 7.3 | 0.5 | 100.0 | 1.6026 | 44.2 | 3.40 |
| 101..... | 43.8 | ... | .. | .3 | 38.1 | 3.1 | ... | 6.5 | 8.3 | ... | 100.0 | 1.619 | 37.6 | ... |
| 102..... | 42.8 | ... | .. | .5 | 32.6 | 5.1 | ... | 10.8 | 7.5 | 0.7 | 100.0 | 1.6269 | 39.1 | 3.70 |
| Borate Glasses | | | | | | | | | | | | | | |
| 103..... | ... | 69.1 | .. | 18.0 | 0.2 | ... | ... | 4.7 | ... | 8.0 | 100.0 | 1.5085 | 60.4 | 2.24 |
| 104..... | ... | 63.8 | .. | 18.0 | .2 | 3.0 | ... | 3.5 | 3.5 | 8.0 | 100.0 | 1.5101 | 58.9 | 2.2 |
| 105..... | ... | 56.0 | .. | 12.0 | ... | 32.0 | ... | ... | ... | ... | 100.0 | 1.5734 | 46.9 | 3.0 |
| 106..... | ... | 49.7 | .. | 13.0 | 0.3 | 37.0 | ... | ... | ... | ... | 100.0 | 1.6130 | 44.4 | 3.17 |
| 107..... | ... | 46.5 | .. | 7.5 | .2 | 46.0 | ... | ... | ... | ... | 100.0 | 1.6287 | 42.5 | .. |
| 108..... | ... | 42.8 | .. | 5.0 | .2 | 52.0 | ... | ... | ... | ... | 100.0 | 1.6659 | 39.2 | 3.69 |

Table 3 (continued).

Borate Glasses (continued)

| No. | SiO ₂ | B ₂ O ₃ | Al ₂ O ₃ | As ₂ O ₃ | PbO | ZnO | CaO | BaO | K ₂ O | Na ₂ O | Total | <i>n_D</i> | <i>r</i> | <i>d</i> |
|-------------------|------------------|-------------------------------|--------------------------------|--------------------------------|-----|-----|------|------|------------------|-------------------|-------|----------------------|----------|----------|
| 109..... | ... | 41.0 | .. | .. | ... | ... | 59.0 | ... | ... | ... | 100.0 | 1.6525 | 50.8 | 3.53 |
| 110..... | ... | 71.8 | .. | 22.4 | ... | ... | ... | ... | ... | ... | 100.0 | 1.5232 | 61.4 | 2.24 |
| 111..... | ... | 64.0 | .. | 30.0 | ... | ... | ... | ... | ... | ... | 100.0 | 1.5194 | 60.9 | 2.21 |
| Phosphate Glasses | | | | | | | | | | | | | | |
| 112..... | ... | 3.0 | 70.5 | 10.0 | 0.5 | ... | ... | ... | 12.0 | ... | 100.0 | 1.5159 | 70.0 | 2.59 |
| 113..... | ... | 3.0 | 69.5 | 10.0 | 1.5 | ... | ... | ... | 12.0 | ... | 100.0 | 1.5215 | 69.7 | 2.59 |
| 114..... | ... | 3.0 | 59.5 | 8.0 | 1.5 | ... | ... | 28.0 | ... | ... | 100.0 | 1.5583 | 67.0 | 3.07 |
| 115..... | ... | 3.0 | 56.0 | 1.5 | 1.5 | ... | ... | 38.0 | ... | ... | 100.0 | 1.5670 | 65.6 | 3.24 |
| 116..... | ... | 3.0 | 54.0 | 1.5 | 1.5 | ... | ... | 40.0 | ... | ... | 100.0 | 1.5760 | 65.2 | 3.35 |
| 117..... | ... | 3.0 | 45.0 | .. | 2.0 | ... | ... | 50.0 | ... | ... | 100.0 | 1.5906 | 64.1 | 3.66 |

LEGEND

Ordinary Crowns

- 1 Ordinary crown..... Zsch. 69 (W 91). With Mn₂O₃, 0.1.
- 2 Crown plate-glass..... Fiedlen, Germany. E. T. Allen, analyst. With Al₂O₃ + Fe₂O₃, 0.08; Sb₂O₃, 0.51.
- 3 Crown plate-glass..... Pittsburgh Plate Glass Co. E. T. Allen, analyst. With Al₂O₃ + Fe₂O₃, 0.09.
- 4 Ordinary crown..... Zsch. 80. With Mn₂O₃, 0.1.
- 5 Light crown..... Spencer Lens Co. C. N. Fenner. *J. Am. Ceram. Soc.*, 2, 143 (1919).
- 6 Hard crown..... Chance Bros. Zsch. 31. With Al₂O₃ + Fe₂O₃, 0.3. P. D.: *F-C* = 0.00856; *F-D* = 0.00604; *G'-F* = 0.00484.

Table 3 (continued)

Borosilicate Crowns

| | | |
|----|-------------------------|---|
| 7 | Borosilicate crown..... | Schott o 144. E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1 , 784 (1918). With Fe_2O_3 , 0.1; As_2O_3 , 0.20; H_2O , 0.08; SO_3 , 0.12; Cl, 0.06. |
| 7 | Borosilicate crown..... | Schott o 144. Zsch. 137 (W 88). With Mn_2O_3 , 0.1. P. D.: $F-C = 0.00797$; $D-A' = 0.00519$; $F-D = 0.00559$; $G'-F = 0.00446$. |
| 9 | Borosilicate crown..... | Schott o 144 (o 1948). Zsch. 138. |
| 10 | Borosilicate crown..... | Spencer Lens Co. C. N. Fenner. <i>J. Am. Ceram. Soc.</i> , 2 , 143 (1919). |
| 11 | Borosilicate crown..... | Schott o 144 (o 627). Zsch. 141. (W 49, 87). With Mn_2O_3 , 0.1. |
| 12 | Borosilicate crown..... | Schott G 59 III. Zsch. 152. Thermometer glass. |
| 13 | Borosilicate crown..... | Schott o 802 (o 1450). Zsch. 153. (W 5). P. D.: $F-C = 0.00765$; $D-A' = 0.00504$; $F-D = 0.00534$; $G'-F = 0.00423$. |
| 14 | Borosilicate crown..... | National Opt. Co. E. T. Allen, analyst. With Fe_2O_3 , 0.04; PbO , 0.12; MgO , 0.09; H_2O , 0.06; SO_3 , 0.02; Cl, 0.05. |
| 15 | Borosilicate crown..... | Schott o 599. Zsch. 134. With Mn_2O_3 , 0.1. P. D.: $F-C = 0.00813$; $D-A' = 0.00529$; $F-D = 0.00569$; $G'-F = 0.00457$. |
| 16 | Borosilicate crown..... | Schott o 599. E. T. Allen, analyst. With $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$, 0.88; H_2O , 0.16; SO_3 , 0.06. |
| 17 | Borosilicate crown..... | Schott o 3832. E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1 , 784 (1918). With Fe_2O_3 , 0.01; As_2O_3 , 0.22; MgO , 0.07; H_2O , 0.06; SO_3 , 0.08; Cl, 0.06. P. D.: $F-C = 0.00806$; $D-A' = 0.00528$; $F-D = 0.00566$; $G'-F = 0.00448$. |
| 18 | Borosilicate crown..... | Schott o 40 (o 55). Zsch. 136 (W 52, 80). With Mn_2O_3 , 0.1. P. D.: $F-C = 0.00849$; $D-A' = 0.00545$; $F-D = 0.00596$; $G'-F = 0.00479$. |
| 19 | Borosilicate crown..... | Schott o 453 (o 4418). Zsch. 146. P. D.: $F-C = 0.00860$; $D-A' = 0.00550$; $F-D = 0.00605$; $G'-F = 0.00486$. |
| 20 | Borosilicate crown..... | Schott o 374 (o 662). Zsch. 139 (W 56). P. D.: $F-C = 0.00844$; $D-A' = 0.00547$; $F-D = 0.00593$; $G'-F = 0.00479$. |

Table 3 (continued)

Borosilicate Crowns (continued)

| | | |
|----|-------------------------|--|
| 21 | Borosilicate crown..... | National Opt. Co. E. T. Allen, analyst. With Fe_2O_3 , 0.05; Mn_2O_3 , 0.03; MgO , 0.17; H_2O , 0.10; SO_3 , 0.20. |
| 22 | Borosilicate crown..... | Schott o 546 (o 518). Zsch. 140. P. D.: $F-C = 0.00859$; $D-A' = 0.00555$; $F-D = 0.00605$; $G'-F = 0.00485$. |
| 23 | Borosilicate crown..... | Schott o 60 (o 122, o 1092). Zsch. 142 (W 60, 77). P. D.: $F-C = 0.00853$; $D-A' = 0.00555$; $F-D = 0.00601$; $G'-F = 0.00489$. |
| 24 | Borosilicate crown..... | Schott o 60. Zsch. 143 (W 28). P. D.: $F-C = 0.00860$; $D-A' = 0.00553$; $F-D = 0.00605$; $G'-F = 0.00487$. |
| 25 | Borosilicate crown..... | Schott o 608. Zsch. 131. With Sb_2O_3 , 20.0. P. D.: $F-C = 0.00943$; $D-A' = 0.00595$; $F-D = 0.00666$; $G'-F = 0.00543$. |

Zinc Silicate Crown

| | | |
|----|--------------------------|---|
| 26 | Zinc silicate crown..... | Schott o 709. Zsch. 16 (W 25, 79). P. D.: $F-C = 0.00894$; $D-A' = 0.00575$; $F-D = 0.00630$; $G'-F = 0.00508$. |
|----|--------------------------|---|

Barium Crowns

| | | |
|----|-------------------|--|
| 27 | Barium crown..... | Schott o 227 (o 3855). Zsch. 145. P. D.: $F-C = 0.00909$; $D-A' = 0.00582$; $F-D = 0.00639$; $G'-F = 0.00514$. |
| 28 | Barium crown..... | Schott o 227. E. Zies, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Fe_2O_3 , 0.02. |
| 29 | Barium crown..... | Schott o 211 (o 885). Zsch. 144 (W 48). |
| 30 | Barium crown..... | Spencer Lens Co. C. N. Fenner. <i>J. Am. Ceram. Soc.</i> , 2, 143 (1919). |
| 31 | Barium crown..... | Schott o 211 (o 4556). Zsch. 147. |
| 32 | Barium crown..... | Schott o 211. Zsch. 150 (W 85). With Mn_2O_3 , 0.1. P. D.: $F-C = 0.00995$; $D-A' = 0.00630$; $F-D = 0.00702$; $G'-F = 0.00588$. |

Table 3 (continued)

Barium Crowns (continued)

| | | |
|----|-------------------|--|
| 33 | Barium crown..... | Schott o 211 (o 1143). Zsch. 149. With Mn_2O_3 , o.1. P. D.: $F-C = 0.01006$; $D-A' = 0.00640$; $F-D = 0.00704$; $G'-F = 0.00584$. |
| 34 | Barium crown..... | Schott o 211. E. T. Allen, analyst. With Fe_2O_3 , o.01; MgO , o.02; H_2O , o.14; SO_3 , o.04; Cl , o.03. |
| 35 | Barium crown..... | Schott o 211 (o 1580). Zsch. 148. |
| 36 | Barium crown..... | Schott o 722. Zsch. 133. |
| 37 | Barium crown..... | Schott o 722. E. Zies, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 = 0.09$; $\text{As}_2\text{O}_5 = 0.55$. P. D.: $F-C = 0.01078$; $D-A' = 0.00681$; $F-D = 0.00761$; $G'-F = 0.00621$. |
| 38 | Barium crown..... | Schott o 1209 (o 1922). Zsch. 151. With Mn_2O_3 , o.1. |
| 39 | Barium crown..... | Schott o 1209. E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Fe_2O_3 , o.02; As_2O_5 , 0.49. P. D.: $F-C = 0.01068$; $D-A' = 0.00680$; $F-D = 0.00753$; $G'-F = 0.00610$. |
| 40 | Barium crown..... | Schott o 2122. Zsch. 161. P. D.: $F-C = 0.00970$; $D-A' = 0.00621$; $F-D = 0.00683$; $G'-F = 0.00546$. |
| 41 | Barium crown..... | Schott o 2122; E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 = 5.11$. |
| 42 | Barium crown..... | Mantois. Zsch. 127. |
| 43 | Barium crown..... | Schott o 1029 (o 1299). Zsch. 162 (W 15, 23). With Mn_2O_3 , o.1. P. D.: $F-C = 0.01068$; $D-A' = 0.00680$; $F-D = 0.00753$; $G'-F = 0.00610$. |
| 44 | Barium crown..... | Schott o 2071. E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Al_2O_3 , 5.02; As_2O_5 , 0.55. |
| 45 | Barium crown..... | Schott o 2071. Zsch. 160. P. D.: $F-C = 0.01037$; $D-A' = 0.00665$; $F-D = 0.00730$; $G'-F = 0.00590$. |

Table 3 (continued)

Flints

| | | |
|----|------------------------------|---|
| 46 | Crown of high dispersion.... | Schott o 114. Zsch. 98. P. D.: $F-C = 0.00910$; $D-A' = 0.00577$; $F-D = 0.00642$; $G'-F = 0.00521$. |
| 47 | Flint..... | Schott o 381 (o 1151). Zsch. 30. With Mn_2O_3 , 0.1. P. D.: $F-C = 0.01026$; $D-A' = 0.00644$; $F-D = 0.00727$; $G'-F = 0.00596$. |
| 48 | Flint..... | Schott o 381 (o 1168). Zsch. 29 (W 55). |
| 49 | Flint..... | Schott o 381. E. Posnjak, analyst. With Fe_2O_3 , 0.02; Mn_2O_3 , 0.04; H_2O , 0.15. |
| 50 | Flint..... | Schott o 381 (o 2074). Zsch. 27. With Mn_2O_3 , 0.1. |
| 51 | Flint..... | Schott o 381 (o 1335). Zsch. 20. |
| 52 | Flint..... | Schott o 726 (o 3149). Zsch. 86. P. D.: $F-C = 0.01142$; $D-A' = 0.00711$; $F-D = 0.00810$; $G'-F = 0.00669$. |
| 53 | Flint..... | Schott o 378 (o 3807). Zsch. 88. P. D.: $F-C = 0.01193$; $D-A' = 0.00739$; $F-D = 0.00847$; $G'-F = 0.00705$. |
| 54 | Flint..... | Schott o 154. E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Fe_2O_3 , 0.02; As_2O_3 , 0.14; H_2O , 0.20; Cl, 0.06. P. D.: $F-C = 0.01327$; $D-A' = 0.00819$; $F-D = 0.00943$; $G'-F = 0.00791$. |
| 55 | Flint..... | Schott o 154. Zsch. 89 (W 47). With Mn_2O_3 , 0.1. |
| 56 | Flint..... | Schott o 569 (o 451). Zsch. 90. With Mn_2O_3 , 0.1. P. D.: $F-C = 0.01385$; $D-A' = 0.00853$; $F-D = 0.00987$; $G'-F = 0.00831$. |
| 57 | Flint..... | Schott o 340. E. T. Allen, analyst. With Fe_2O_3 , 0.02; H_2O , 0.09; SO_3 , 0.10; Cl, 0.03. P. D.: $F-C = 0.01396$; $D-A' = 0.00857$; $F-D = 0.00994$; $G'-F = 0.00837$. |
| 58 | Flint..... | Spencer Lens Co. C. N. Fenner. <i>J. Am. Ceram. Soc.</i> , 2, 143 (1919). |
| 59 | Flint..... | Schott 318 (o 4366). Zsch. 91. P. D.: $F-C = 0.01575$; $D-A' = 0.00960$; $F-D = 0.01124$; $G'-F = 0.00952$. |
| 60 | Flint..... | Spencer Lens Co. C. N. Fenner. <i>J. Am. Ceram. Soc.</i> , 2, 143 (1919). |

Table 3 (continued)

Flints (continued)

| | | |
|----|------------|--|
| 61 | Flint..... | Schott o 118 (o 4271). Zsch. 92. P. D.: $F-C = 0.01660$; $D-A' = 0.01006$; $F-D = 0.01184$; $G'-F = 0.01008$. |
| 62 | Flint..... | Schott o 167. E. Zies, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Fe_2O_3 , 0.02; H_2O , 0.03; SO_3 , 0.10. |
| 63 | Flint..... | National Opt. Co. E. T. Allen, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Fe_2O_3 , 0.03; H_2O , 0.06. |
| 64 | Flint..... | Schott o 93 (o 4237). Zsch. 94. P. D.: $F-C = 0.01743$; $D-A' = 0.01053$; $F-D = 0.01243$; $G'-F = 0.01063$. |
| 65 | Flint..... | Schott o 331. Zsch. 95. With Mn_2O_3 , 0.1. |
| 66 | Flint..... | Mantois. Zsch. 93. |
| 67 | Flint..... | Schott o 118. Zsch. 50. P. D.: $F-C = 0.01660$; $D-A' = 0.01006$; $F-D = 0.01184$; $G'-F = 0.01008$. |
| 68 | Flint..... | Schott o 118. E. T. Allen, analyst. With $\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 = 0.03$. |
| 69 | Flint..... | Schott o 118 (o 479). Zsch. 47 (W 46). |
| 70 | Flint..... | Schott o 118 (o 1469). Zsch. 52. With Mn_2O_3 , 0.1. |
| 71 | Flint..... | Schott o 103 (o 2512). Zsch. 49. P. D.: $F-C = 0.01709$; $D-A' = 0.01034$; $F-D = 0.01220$; $G'-F = 0.01041$. |
| 72 | Flint..... | Schott o 102 (o 4591). Zsch. 53. P. D.: $F-C = 0.01919$; $D-A' = 0.01152$; $F-D = 0.01372$; $G'-F = 0.01180$. |
| 73 | Flint..... | Spencer Lens Co. C. N. Fenner. <i>J. Am. Ceram. Soc.</i> , 2, 143 (1919). |
| 74 | Flint..... | Schott o 102 (o 1571). Zsch. 54 (W 26). With Mn_2O_3 , 0.1. |
| 75 | Flint..... | Schott o 102. E. Posnjak, analyst. With Fe_2O_3 , 0.02; H_2O , 0.08. |
| 76 | Flint..... | Schott o 102 (o 469). Zsch. 55. With Mn_2O_3 , 0.1. P. D.: $F-C = 0.01927$; $D-A' = 0.01161$; $F-D = 0.01382$; $G'-F = 0.01194$. |
| 77 | Flint..... | Schott o 192 (o 3570). Zsch. 101. |

Table 3 (continued)

| Flints (continued) | |
|----------------------------|--|
| 78 Flint..... | Schott o 192. Zsch. 57. P. D.: $F-C = 0.02104$; $D-A' = 0.01255$; $F-D = 0.01507$; $G'-F = 0.01302$. |
| 79 Flint..... | Schott o 41 (o 4113). Zsch. 96. |
| 80 Flint..... | Schott o 41. Zsch. 58. P. D.: $F-C = 0.02434$; $D-A' = 0.01439$; $F-D = 0.01749$; $G'-F = 0.01521$. |
| 81 Flint..... | Schott o 165 (o 500). Zsch. 59 (W 33). P. D.: $F-C = 0.02723$; $D-A' = 0.01600$; $F-D = 0.01961$; $G'-F = 0.01709$. |
| 82 Flint..... | Schott o 165. Zsch. 60 (W 50). P. D.: $F-C = 0.02743$; $D-A' = 0.01607$; $F-D =$ 0.01974 ; $G'-F = 0.01730$. |
| 83 Flint..... | Schott o 198. Zsch. 61. P. D.: $F-C = 0.02941$; $D-A' = 0.01719$; $F-D = 0.02120$; $G'-F = 0.01868$. |
| 84 Flint..... | Schott S 163. Zsch. 110 (W 18). P. D.: $F-C = 0.03997$; $D-A' = 0.02293$; $F-D =$ 0.02895 ; $G'-F = 0.02603$. |
| 85 Flint..... | Schott S 231. Zsch. 111 (W 64). |
| 86 Flint..... | Schott S 208. Zsch. 112 (W 20). |
| 87 Flint..... | Schott S 57. Zsch. 113. P. D.: $F-C = 0.04882$; $D-A' = 0.02767$; $F-D = 0.03547$; $G'-F = 0.03252$. |
| Borosilicate Flint | |
| 88 Borosilicate flint..... | Schott o 161. Zsch. 157. P. D.: $F-C = 0.01216$; $D-A' = 0.00762$; $F-D = 0.00860$; $G'-F = 0.00709$. |
| Barium Flint | |
| 89 Barium flint..... | Schott o 846 (o 3666). Zsch. 103. P. D.: $F-C = 0.01042$; $D-A' = 0.00657$; $F-D = 0.00736$; $G'-F = 0.00602$. |

Table 3 (continued)

Barium Flint (continued)

| | | |
|-----|-------------------|--|
| 90 | Barium flint..... | Schott o 522 (o 3633). Zsch. 100. P. D.: $F-C = 0.01153$; $D-A' = 0.00718$; $F-D' = 0.00819$; $G'-F = 0.00677$. |
| 91 | Barium flint..... | Schott o 543 (o 3868). Zsch. 106. |
| 92 | Barium flint..... | Schott o 543. Zsch. 107. P. D.: $F-C = 0.01115$; $D-A' = 0.00699$; $F-D = 0.00790$; $G'-F = 0.00650$. |
| 93 | Barium flint..... | Schott o 527. Zsch. 104. P. D.: $F-C = 0.01133$; $D-A' = 0.00706$; $F-D = 0.00803$; $G'-F = 0.00660$. |
| 94 | Barium flint..... | Schott o 527 (o 3187). Zsch. 105. |
| 95 | Barium flint..... | Schott o 602 (o 3524). Zsch. 102. P. D.: $F-C = 0.01072$; $D-A' = 0.00675$; $F-D = 0.00759$; $G'-F = 0.00618$. |
| 96 | Barium flint..... | Schott o 578 (o 4542). Zsch. 108. |
| 97 | Barium flint..... | Schott o 578. E. Posnjak, analyst. <i>J. Am. Ceram. Soc.</i> , 1, 784 (1918). With Fe_2O_3 , 0.01; As_2O_5 , 0.31; H_2O , 0.08. P. D.: $F-C = 0.01255$; $D-A' = 0.00777$; $F-D = 0.00891$; $G'-F = 0.00739$. |
| 98 | Barium flint..... | Schott o 578 (o 1398). Zsch. 109. With Mn_2O_3 , 0.1. P. D.: $F-C = 0.1244$; $D-A' = 0.00774$; $F-D = 0.00896$; $G'-F = 0.00742$. |
| 99 | Barium flint..... | Schott o 1266 (o 3111). Zsch. 64. With Mn_2O_3 , 0.1. P. D.: $F-C = 0.01381$; $D-A' = 0.0851$; $F-D = 0.00982$; $G'-F = 0.00821$. |
| 100 | Barium flint..... | Schott o 1266 (o 1777). Zsch. 65. With Mn_2O_3 , 0.1. |
| 101 | Barium flint..... | Spencer Lens Co. C. N. Fenner. <i>J. Am. Ceram. Soc.</i> , 2, 146 (1919). |
| 102 | Barium flint..... | Schott o 748 (o 4534). Zsch. 66. P. D.: $F-C = 0.01599$; $D-A' = 0.00965$; $F-D = 0.01142$; $G'-F = 0.00965$. |

Borate Glass

| | | |
|-----|-------------------|--------------------------------|
| 103 | Borate glass..... | Schott S 196. Zsch. 171 (W 2). |
| 104 | Borate glass..... | Schott S 204. Zsch. 173. |

Table 3 (continued)

| Borate Glass (continued) | |
|--------------------------|---|
| 105 Borate glass..... | Schott V S 428. Zsch. 167 (W 42). |
| 106 Borate glass..... | Schott S 4. Zsch. 168. |
| 107 Borate glass..... | Schott S 99. Zsch. 169. |
| 108 Borate glass..... | Schott S 120. Zsch. 170 (W 16). |
| 109 Borate glass..... | Schott V S 665. Zsch. 164. |
| 110 Borate glass..... | Schott S 185. Zsch. 165 (W 1). With Li_2O , 5.8. |
| 111 Borate glass..... | Schott V S 458. Zsch. 166 (W 43). With Li_2O , 6.0. |
| Phosphate Glass | |
| 112 Phosphate glass..... | Schott 0 225. Zsch. 179 (W 9, 57). With MgO , 4.0. P. D.: $F-C = 0.00737$; $D-A' = 0.00485$; $F-D = 0.00515$; $G'-F = 0.00407$. |
| 113 Phosphate glass..... | Schott S 219. Zsch. 178 (W 27). With MgO , 4.0. |
| 114 Phosphate glass..... | Schott S 206. Zsch. 177 (W 13). |
| 115 Phosphate glass..... | Schott S 95. Zsch. 174 (W 14). |
| 116 Phosphate glass..... | Schott S 30. Zsch. 175. P. D.: $F-C = 0.00884$; $D-A' = 0.00570$; $F-D = 0.00622$; $G'-F = 0.00500$. |
| 117 Phosphate glass..... | Schott S 15. Zsch. 176. P. D.: $F-C = 0.00922$; $D-A' = 0.00591$; $F-D = 0.00648$; $G'-F = 0.00521$. |

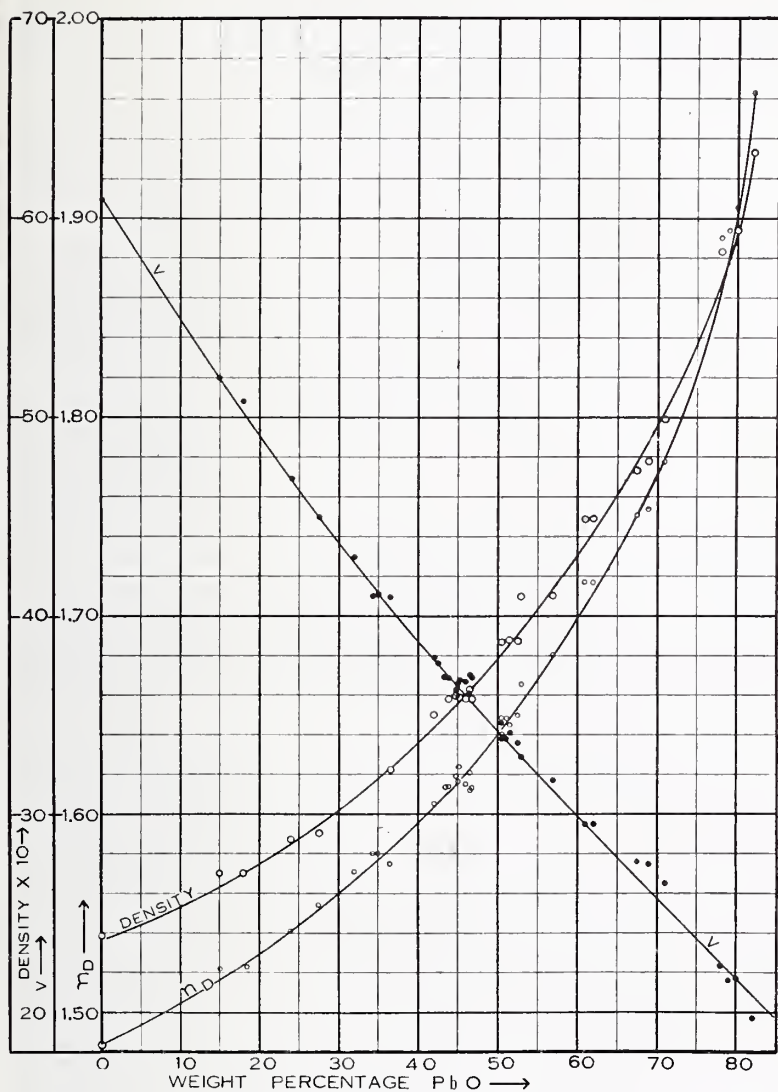


FIG. 9.—In this diagram are shown the changes in the density and the optical constants (refractive index n_D , and v -value) with change in lead oxide (PbO) in the flint series of glasses.

position-refractivity relations were deduced from it. The chemical relations (weight percentages) were plotted on a triaxial diagram such as is commonly used in representing the relations in a three-component chemical system.

The fact that, for the members of the flint series, the refractivity relations are expressed by means of smooth continuous curves in the diagrams in the optical part of this paper, indicates that this series is analogous in its behavior, so far as the glasses are concerned, to a two-component system. If so, the chemical compositions of these glasses, when plotted in the triaxial diagram, should be found to fall on a straight line. In figure 8 the weight percentage compositions are plotted directly; the three components are silica (SiO_2), lead oxide (PbO), and the alkali oxides (Na_2O , K_2O). The points on the diagram include all available compositions of flint glasses. The potash flints are distinguished in the diagram from the soda-potash flints and from the soda flints. The compositions of all the glasses plotted fall practically on a straight line between the compositions: lead metasilicate ($\text{PbO} \cdot \text{SiO}_2$) and the potassium silicate glass of the composition $\text{K}_2\text{O} \cdot 6\text{SiO}_2$, or the sodium silicate glass of the approximate composition $\text{Na}_2\text{O} \cdot 4\text{SiO}_2$. The optical constants of a synthetic potassium silicate glass of this composition were found to be: $n_D = 1.4836$; $\nu = 61.0$

The entire flint series is analogous chemically to a two-component mixture and, as such, any one of its physical constants, such as refractive index, ν -value, or density, varies continuously with change in composition. This variation is illustrated in figure 9, in which the variation in the chemical composition is represented along the abscissa axis as weight percentages of lead oxide. The ordinates give then the values of the refractive index for sodium light, the ν -value, and the density for the glasses of the several compositions. Smooth curves passing through these points enable the observer to read off the percentage of lead oxide required in a glass having any desired constant represented on these curves. In figure 10 the changes in other optical constants (partial dispersions, ν -value) as well as in lead oxide content, with change in refractive index n_D , are represented for all Schott and Chance flint and ordinary crown glasses. These

changes are represented in the flint series by smooth continuous curves. The diagram shows that the flint glasses are characterized by higher dispersions and a more rapid relative rise in dispersion

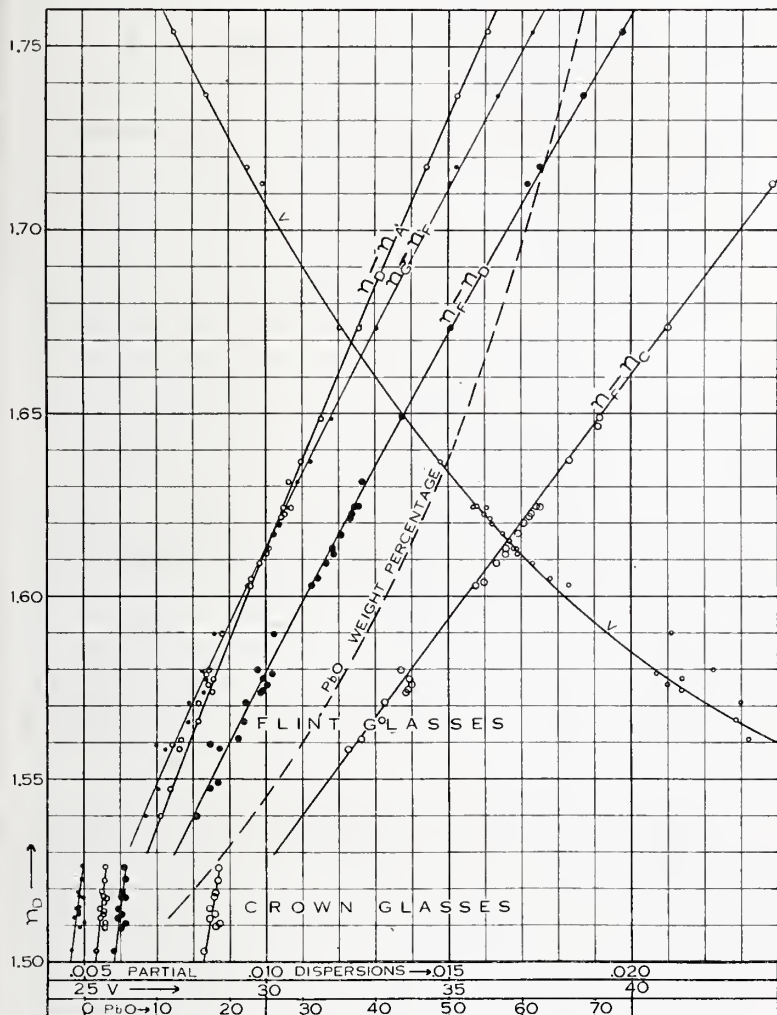


FIG. 10.—In this diagram the changes in partial dispersions, partial dispersion ratio, v -values, density, and in lead content with change in refractive index are shown.

with rise in refractive index than is the case in the ordinary crown glasses.

The foregoing three figures represent the sum total of empirical efforts on the part of glass-makers to produce a series of flint glasses which have certain optical properties. The reason for the straight composition-line of figure 8 is not far to seek. Glasses very high in silica are extremely viscous and melt at such high temperatures that they can not be made in furnaces of the ordinary type. On the other hand, glasses high in alkalis are extremely hygroscopic and therefore unsuitable for optical purposes. Glasses high in lead crystallize with great ease and hence are unsuitable from the glass-maker's standpoint. The glass-maker is thus forced to adopt those compositions which melt readily, which are not hygroscopic, and which do not crystallize too readily on cooling from high temperatures. An extended series of experiments by Mr. Olaf Andersen of the Geophysical Laboratory, carried out in the laboratory on a small scale in platinum crucibles, corroborated the above conclusions in detail. The results of his studies are to be published later.

In figure 11 a composite diagram of the relations in both the crown and flint silicate glasses of table 3 is presented. The range of compositions in this diagram, as in figure 8, is restricted to a fairly definite band; the reasons for this narrow belt of compositions are given in the foregoing paragraph. Although there is more leeway here for the glass-maker in the matter of compositions, there are certain definite limits beyond which he may not pass without inviting trouble and loss.

Computation of Batches from Chemical Analyses of Glasses

In preparing a batch to reproduce a glass of given optical constants it is necessary for the operator to take into consideration the losses incurred by selective volatilization of the batch components. The amounts lost during the melting and fining processes depend on the size and character of the batch, the character and temperatures of the furnace, the method of filling in the batch, the type of the melting pot, whether open, semi-closed, or closed, the duration of the operations, and the character of the stirring, so that it is not possible to give more than rough per-

centage estimates of these factors. A few experiments suffice, however, to determine the relations for a given set of operating conditions; once these have been ascertained the glass-maker endeavors to adhere to them strictly and thus to insure uniformity in the final product. In the computation of the batch mixtures the following allowances are made for losses by selective volatilization: PbO or Pb_3O_4 0.5 to 5 per cent, and even higher;¹ boric

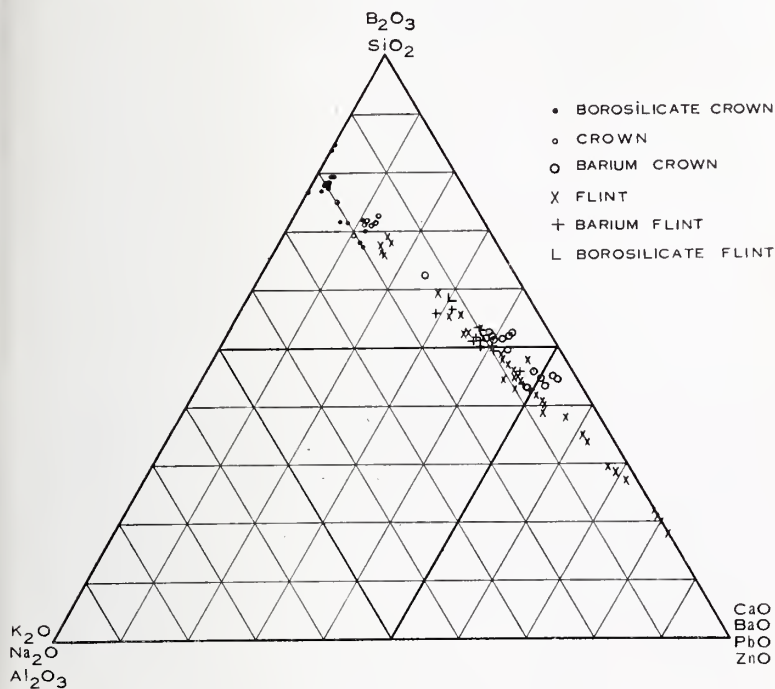


FIG. 11.—Triaxial diagram showing the weight percentage compositions of the ordinary crowns, borosilicate crowns, barium crowns, flints, barium flints, and borosilicate flints of Table 3.

oxide 1 to 5 per cent in case boric acid rather than borax is used in the batch; the alkalis, K_2O and Na_2O , up to 5 per cent. Little definite information is available on the losses incurred by selective volatilization and in a given case much depends on the factors

¹ See Olaf Andersen. The volatilization of lead oxide from lead silicate melts, *J. Am. Ceram. Soc.*, 2, 784 (1919).

already mentioned. At the present time it is a matter largely of experience and of actual trial to make proper allowance for these factors. As a result of this volatilization the batch becomes relatively richer in silica and the refractive index of the finished glass is lowered.

From the relations presented in foregoing paragraphs it is possible to prepare a plot from which the batch composition for any member of the flint series can be read off directly (figure 12). This plot is constructed on the basis of sand 100 units of weight (pounds or kilograms). Thus from the diagram the batch composition in kilograms for the flint glass of refractive index $n_D = 1.640$, we read: Sand 100, lead oxide (PbO) 119 or (Pb₃O₄) 122; anhydrous potassium carbonate (K₂CO₃) 20.6; potassium nitrate (KNO₃) 7.0. Sodium oxide in the form of sodium carbonate or sodium nitrate may be substituted for potassium oxide provided the amount of Na₂O (weight percentage) equals in weight the amount of K₂O which it replaces; substitution of Na₂O for K₂O raises the refractive index slightly, decreases the ν -value slightly and changes the viscosity relations noticeably. Flint glasses high in soda exhibit a tendency to be duller, less transparent, and more noticeably colored than the corresponding pure potash flints. The density and ν -value of any glass of given PbO or Pb₃O₄-content are indicated on the plot (figure 12) by the intersections of the PbO or Pb₃O₄ ordinate with the curves for density and ν -value respectively; thus in the foregoing example the density of the flint glass $n_D = 1.640$ is $d = 3.78$ and its ν -value is 34.5. The batch composition for a flint glass of ν -value = 46.0 is, in kilograms: sand 100; PbO 44.5 or Pb₃O₄ 45.5; K₂CO₃ 7.6; KNO₃ 2.2. Its density is 2.93 and its $n_D = 1.549$.

The compositions of glasses of other types can be ascertained by means of the compositions given in table 3, together with the data plotted especially on figures 4 and 11. It would lead too far in the present paper to consider these systems in detail; in some of them the information at hand is meager and hardly sufficient for satisfactory interpolation; but in most instances the glass-maker, with the aid of these methods and the data now available, is able to write down batches which approach very closely the batch desired, so that with a few experimental melts

in small crucibles he can determine the correct batch composition within very narrow limits.

The foregoing diagrams indicate clearly the fields which are dominated by the different oxides; in view of these relations it is, therefore, fitting to name the silicate glasses as has been done: crown crowns, borosilicate crowns, ordinary crowns, and barium crowns; flints, barium flints, and borosilicate flints. Zinc-bearing glasses do not require separate designation because zinc oxide

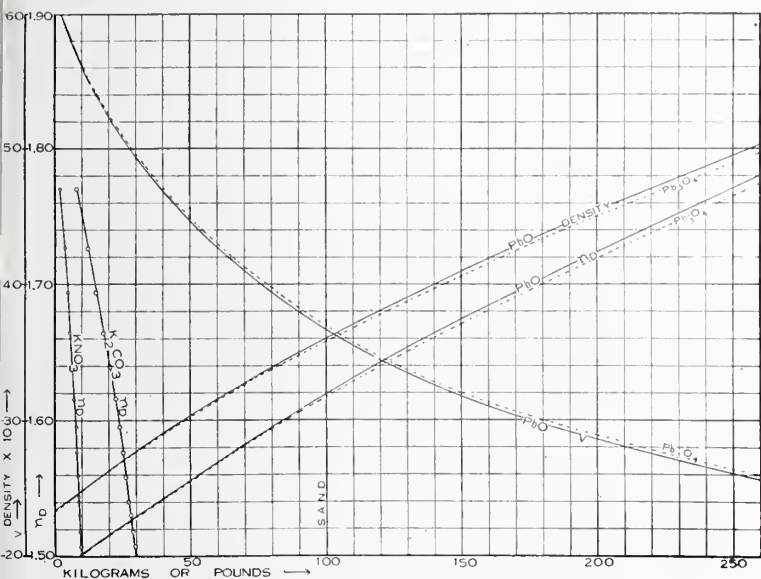


FIG. 12.—Batch composition diagram for the series of optical flint glasses.

in optical glasses does not impart special optical properties to the glass; it serves chiefly to change the concentration and viscosity relations in optical glass melts, especially to render the melt easier to work and to decrease the tendency to crystallize on cooling. In the flint series the light, medium, and dense flints are distinguished. The barium flints are flints in which part of the lead is replaced by barium. In all types of silicate glasses the amount of silica present is relatively large and the optical characteristics

of each glass are in effect a blend of characteristics between those of silica and some other end member or members, with silica commonly dominating.

A study of the above diagrams, especially figure 4, proves that in the silicate optical glasses, lead and barium oxides on the one hand, silica and boron oxide on the other, exert the most profound influence on the optical constants of the glass. Thus the highly refracting glasses contain abundant lead oxide or barium oxide; the low refracting glasses contain abundant silica or boron oxide. Of all the glass-making elements, lead has the most pronounced effect on both the refractive index and the dispersion; it increases especially the blue end of the spectrum relatively to the red.

If in a flint glass of given refractivity, a higher ν -value (lower dispersive power) is desired, part of the lead oxide is replaced by barium oxide (introduced in the batch as barium carbonate). Compared with lead oxide, barium oxide produces less high refractive index and very much weaker dispersion (high ν -value); glasses high in BaO and PbO are called barium or baryta flints. Zinc oxide is intermediate in its action between calcium oxide and lead oxide on the one hand, and barium oxide on the other; like calcium oxide it tends to raise slightly the refractive index and the dispersion. In the series of flint glasses the relative dispersion increases with increase in refractive index; in other words, if, for the sake of comparison, the refractive indices $n_{A'}$, n_C , n_F , $n_{G'}$, for each member of the series are divided by the refractive index n_D , then the ratios increase with rise in refractive index n_D the characteristic feature of the dispersion of lead glasses is the rapid rise in refractivity toward the blue and violet end of the spectrum. The same relations are clearly shown in a diagram in which the ratios $\frac{n_D - n_{A'}}{n_F - n_D}$ and $\frac{n_{G'} - n_F}{n_F - n_D}$ are plotted as abscissae against the refractive index as ordinates.

Increase in silica, boron oxide, or fluorine tends, on the other hand, to lower the refractive index, to increase relatively the dispersion of the red end of the spectrum and at the same time to decrease the total dispersion. This lengthening of the red end

of the spectrum is especially true of boron oxide and of fluorine.¹

The addition or substitution of small amounts of boron oxide slightly raises the refractive index of certain glasses. This behavior is remarkable because by itself the refractive index of boric oxide glass is only $n_D = 1.463$ and the ν -value 59.4; that of silica glass is $n_D = 1.4585$ and the ν -value 67.9. Evidently borates are formed which impart different properties to the glass from those which might be inferred from the characteristics of the individual components.² Similarly alumina (Al_2O_3), which in the crystallized state has a very high refractive index (1.76), produces with silica a glass of unexpectedly low refractivity. Alumina and magnesia raise the viscosity of most glass melts and tend thereby to prevent crystallization.

Phosphorus, although formerly used in appreciable amounts, especially in the series of phosphate glasses, has now been discarded because of the poor weather-resistant qualities of the phosphate glasses. Figure 4 shows that these glasses differ only slightly from the borosilicates and the barium crowns; this difference does not outweigh the practical disadvantage of weathering instability.

The essential differences between the ordinary flints and ordinary crowns are the higher refractivity and the greater dispersion, both actual and relative, in the flint glasses, especially in the blue end of the spectrum. With these two types of glasses it is not possible therefore to compensate exactly the dispersive effects of a positive crown element by a negative flint element and secondary spectrum results. By the use of glasses in which the relative dispersions are more nearly similar than between the crowns and flints, it is possible to correct more perfectly for achromatism; the presence of the two chemical elements, barium and boron, in optical glass shifts the relative dispersions in the crowns and flints so that they are more nearly in accord. By the use of these elements in the flint glasses the extreme dispersions

¹ The statement made by Hovestadt, *Jenaer Glas*, p. 11, 1900, that boron oxide tends to lengthen the red end of the spectrum, whereas fluorine has the opposite effect and tends to decrease the red end relatively to the blue, is not borne out by the fluor-crown glasses.

² See also Zschimmer, *Zeitschr. Elektrochemie*, 11, 632, 1905.

of the blue end of the spectrum in the normal flint glasses are reduced relatively and the course of the dispersion throughout the visible spectrum is rendered more nearly like that of a crown glass.

In writing down the batch for a glass of specified refractive index and dispersion the glass-maker has a number of factors to consider, such as chemical composition, and the changes in composition resulting from selective volatilization and from pot solution. In the series of ordinary crowns and flints, silica (sand), alkalis (potassium and sodium oxides), lime (calcium oxide), and lead oxide are the essential constituents; in these the proportions of the different elements may not exceed certain limits. If the percentage of silica is above 75 per cent the melt is so viscous that it can not be properly melted in the furnace; the percentage of alkalis may not exceed 20 per cent, otherwise the resultant glass is hygroscopic and chemically unstable; over 13 per cent of lime may not be used because of the tendency of melts high in lime to crystallize, and because of the difficulty of fusing such melts properly; lead oxide may be used up to 70 per cent or more, but in glasses containing a large percentage of lead the danger from crystallization and from attack on the melting pot is serious. In the new series of glasses, boron, barium, zinc, and aluminum oxides are the most important additional constituents which are employed; up to 50 per cent barium oxide may be used, but then ordinarily together with boron and alumina; melts high in barium attack the crucible seriously, especially if any free silica is present in the clay. The dense barium glass melts require, moreover, special furnace treatment to produce a glass free from bubbles and other defects such as crystallization nuclei.¹ Boron oxide may be used up to 20 per cent or more; it replaces, in a measure, silica. In general the use of small quantities of boric acid in lead glasses is not to be recommended because experience has shown that its presence favors the development of opalescence in the glass on cooling. Zinc in quantities above 12 per cent is likely to cause crystallization of the glass. More than 5 per cent of

¹ Compare N. L. Bowen, *J. Wash. Acad. Sci.*, 8, 265-268 (1918); *J. Am. Ceram. Soc.*, 2, 261-281 (1919).

alumina tends to render certain glass melts exceedingly viscous and practically unworkable at the melting temperatures; the presence of alumina decreases the danger from crystallization and renders the glass tough and resistant. In the densest barium crown glasses up to 10 per cent Al_2O_3 may be used; it aids not only in preventing crystallization of barium disilicate, but it also improves the working qualities of the melt and glass. The presence of chlorine or sulphur in the batch materials is to be avoided because of the danger of opalescence in the finished glass. In case these elements are present, it is advisable to run the melt at a very high temperature.¹

The presence of arsenic in most glasses is favored by most glass-makers because it tends to increase the transparency and brilliancy of the glasses; certain experiments indicate that the presence of arsenic in the melt probably sets up an oxidizing action at high temperatures² and thus reduces the effect of iron as a coloring agent. Although some arsenic is volatilized in the melt, an appreciable amount remains in the solution. Careful analytical work by Allen and Zies³ of the Geophysical Laboratory has demonstrated the presence in optical glasses of arsenic in both states of oxidation, as arsenic trioxide and arsenic pentoxide.

In the preparation of batches the nitrates and carbonates of the alkalis are used in proportions ranging from 1 : 5 to 1 : 2, depending on the type of glass; nitrates alone produce too active a melt, while carbonates alone do not furnish the desired oxidizing agents. Melts high in alkalis and made from batches containing alkali carbonates but no nitrates are difficult to fire properly. The chief function of alkalis in optical glass is to produce melts which are easily workable; they influence the viscosity of the melt; the viscosity of a potassium flint glass melt changes slowly with the temperature; that of a sodium flint glass changes fairly abruptly at a temperature somewhat above the softening

¹ See J. D. Cauwood and W. E. S. Turner, *J. Soc. Glass Techn.*, **1**, 187 (1917); C. N. Fenner and J. B. Ferguson, *J. Am. Ceram. Soc.*, **1**, 468 (1918); C. N. Fenner, *J. Am. Ceram. Soc.*, **2**, 106 (1919).

² See Doelter, *Handbuch der Mineralchemie* (Leipzig), **1**, 861 (1912); also E. T. Allen and E. G. Zies, *J. Am. Ceram. Soc.*, **1**, 787 (1918).

³ *J. Am. Ceram. Soc.*, **1**, 767-794 (1918).

point. Increase in the total alkali content of a glass commonly raises its refractive index slightly; thus in the medium flint glasses an increase in alkalies with corresponding decrease in silica, the percentage of lead oxide remaining the same, raises the refractive index. Both alumina and magnesia may exert a profound effect on the viscosity of the melt. In the computation of batches from chemical analyses the data of table 4 are useful.

TABLE 4.

Table of molecular weights and ratios between molecular weights for use in the computation of glass batches from chemical analyses

| Molecular weights | | | | | | | |
|--|-------|-----------------------------------|---------------------------------|--|-------|-----------------------------------|---------------------------------|
| Al ₂ O ₃ | 102.2 | CoO | 75.0 | Na ₂ O | 62.0 | TiO ₂ | 70.1 |
| As ₂ O ₃ | 197.9 | CaO | 56.1 | NiO | 74.7 | U ₂ O ₃ | 524.4 |
| BaO | 153.4 | FeO | 71.8 | PbO | 223.2 | V ₂ O ₃ | 150.0 |
| Bi ₂ O ₃ | 464.0 | Fe ₂ O ₃ | 159.7 | SeO ₂ | 111.2 | ZnO | 81.4 |
| B ₂ O ₃ | 70.0 | K ₂ O | 94.2 | SiO ₂ | 60.3 | CO ₂ | 44.0 |
| CdO | 128.4 | Li ₂ O | 29.9 | SrO | 103.6 | N ₂ O ₅ | 108.0 |
| CaO | 56.1 | MgO | 40.3 | Sb ₂ O ₃ | 288.4 | Cl ₂ O ₅ | 150.9 |
| Cr ₂ O ₃ | 152.0 | MnO | 70.9 | SnO ₂ | 141.0 | SO ₃ | 80.0 |
| | | Ratio of oxide to salt I | Re- cip- rocal of I II | | | Ratio of oxide to salt I | Re- cip- rocal of I II |
| B ₂ O ₃ to 2B(OH) ₃ | | 0.564 | 1.77 | MgO to MgCO ₃ | | 0.478 | 2.09 |
| Na ₂ B ₄ I ₇ IOH ₂ O | | .366 | 2.73 | | | | |
| Na ₂ B ₄ I ₇ | | .713 | 1.40 | MnO to MnO ₂ | | .816 | 1.23 |
| BaO to BaCO ₃ | | .777 | 1.29 | | | | |
| BaSO ₄ | | .657 | 1.52 | Na ₂ O to Na ₂ CO ₃ | | .585 | 1.71 |
| | | | | Na ₂ SO ₄ | | .437 | 2.29 |
| CaO to CaCO ₃ | | .560 | 1.78 | 2NaNO ₃ | | .365 | 2.74 |
| CaF ₂ | | .718 | 1.39 | Na ₂ B ₄ O ₇ IOH ₂ O | | .162 | 6.11 |
| | | | | Na ₂ B ₄ O ₇ | | .307 | 3.26 |
| K ₂ O to K ₂ CO ₃ | | .682 | 1.47 | | | | |
| K ₂ CO ₃ 2H ₂ O | | .541 | 1.85 | PbO to Pb ₃ O ₄ | | .977 | 1.02 |
| K ₂ SO ₄ | | .541 | 1.85 | PbO ₂ | | .933 | 1.07 |
| 2KNO ₃ | | .466 | 2.15 | | | | |
| 2KClO ₃ | | .384 | 2.61 | | | | |

Practical Applications

As an illustration of the use of the foregoing diagrams the batches for several different types of optical glasses will now be deduced.

(a) Ascertain the batch for an optical glass of refractive index $n_D = 1.649$ and $\nu = 33.7$.

By definition $\nu = (n_D - 1)/(n_F - n_C)$; accordingly the mean dispersion of this glass is $0.649/33.7 = 0.01925$. From figure 2 we find that a glass of these properties is a member of the flint series; we may therefore turn directly to figures 8 to 12 for the desired information; the batch may be read off directly from figure 12 or obtained less directly from figures 8 and 9. The refractive index curve of figure 9 shows that the percentage of lead oxide, PbO, contained in a glass of refractive index $n_D = 1.649$ is 52; from figure 8 in turn we find that the approximate composition of a flint glass containing 52 per cent PbO is: SiO₂ 41, PbO 52, and the alkalis (K₂O, or Na₂O, or $mK_2O + nNa_2O$) 7. By means of the conversion factors listed in table 4 we now convert the K₂O into a mixture of K₂CO₃ and KNO₃ such that the total amount of K₂CO₃ is three times that of KNO₃. A simple algebraic computation shows that this will be the case if 0.814 or roughly four-fifths of the total amount of K₂O is assigned to K₂CO₃ and the rest to KNO₃; the corresponding factor for Na₂O is 0.827. The batch then without allowance for volatilization is: Sand 100 kilograms or pounds, litharge (PbO) 126.8, potassium carbonate (anhydrous K₂CO₃) 20.4, potassium nitrate, 6.8. To correct for volatilization the lead oxide should be increased a little; as a first approximation subject to test and slight modification after a trial melt, we may write: Sand 100, litharge 127 (or red lead, Pb₃O₄, 130), potassium carbonate 20.5, potassium nitrate 6.8, and arsenious oxide (As₂O₃) 0.6,

The batch may also be read off directly from figure 12: sand 100, litharge 127, K₂CO₃ 20, KNO₃ 7. In the batch diagram as given arsenious oxide is not included; it is, however, common practice among glass-makers to add from 0.2 to 1 kilogram As₂O₃ per 100 sand. Too much arsenious oxide, especially in the flint glasses, may cause the glass to turn milky on cooling; but a little is considered to aid in producing a colorless glass of high, brilliant luster.

In case the analysis of the raw materials shows the presence of an appreciable amount of water in any one of the substances, such

as potassium carbonate, proper correction for this should be made in computing the actual batch to be used.

It should be understood that these batch figures are of the correct order of magnitude only; that the nice adjustment of the batch depends on a number of factors which are best ascertained by actual trial; these factors include size and type of melting pot and of melting furnace, resistance of the pot to attack by the glass melt, furnace schedule and treatment of the glass batch and melt. A departure of one or even two units in the third decimal place in the refractive index, and of one or two tenths in the ν -value may be found on actual trial. A slight modification of the relative quantities of the batch substance suffices commonly to produce the desired results.

(b) State the batch compositions of a glass of refractive index $n_D = 1.517$ and $\nu = 64.3$; $n_F - n_C = 0.00804$.

The ν -value of this glass is so high that it is evidently a borosilicate crown. Reference to the analyses of table 3 indicates that the optical constants of glass No. 17 are closely similar to those desired. In general it may be stated that for a borosilicate glass of such high ν -value, the refringence is unusually high, whereas for a crown glass of this refractive index, the ν -value is too high. The presence of boron oxide in the glass raises its ν -value; but, if added in quantity, it lowers the refractive index; barium oxide, on the other hand, tends to raise both the refractive index and the ν -value. It is evident, therefore, that in order to attain the higher refractive index, together with high ν -value, barium oxide should be substituted for the lime of the crown glasses and boron oxide should be present in appreciable quantities in order to approach the type of glass desired. The ν -value of glass No. 17 is too low; in order to raise it slightly the relative amount of boron oxide should be increased somewhat. A batch computed on the basis of analysis of 17 and modified in the manner indicated is the following: sand 100, $B(OH)_3$ 31, K_2CO_3 31, Na_2CO_3 21, KNO_3 5.2, $BaCO_3$ 6, As_2O_3 0.3.

In case a slightly lower ν -value as 64.1 or 64.0 is desired, the amount of $B(OH)_3$ should be reduced to 30 or even 29. The interplay of boron oxide and barium oxide in optical glasses, as affecting their dispersion and refringence, is a most important factor for the glass-maker to realize.

(c) State batch composition of a borosilicate crown of refractive index $n_D = 1.511$, $\nu = 63.5$.

In this glass the refractive index is low and the ν -value high; there is no necessity therefore of substituting BaO for CaO. Analyses 9, 10, and 11 may serve as a basis from which to deduce a batch composition for this glass; thus an appropriate batch would be: sand 100, B(OH)₃ 12, Na₂CO₃ 22.6, K₂CO₃ 15, KNO₃ 9, CaCO₃ 4.5, As₂O₃ 0.4.

(d) Select two glasses which in combination will produce a telescope objective nearly free from secondary spectrum.

Secondary spectrum in a well constructed telescope objective consisting of two glasses in combination results from the dissimilarity of dispersion in the two glasses. It can be readily proved that, other conditions being the same, the amount of secondary spectrum, for any spectrum interval, present in a doublet depends directly on the partial dispersion ratios of the two glasses and inversely on the difference between the ν -values.

The dispersion relations referred to in the foregoing pages enable us to select glasses which meet these requirements. They may in fact be selected directly by inspection of figure 4. As an illustration let it be required to select a suitable glass which may be used in combination with the zinc crown glass No. 26 of table 3 of glass analyses. The optical constants of this glass are: $n_D = 1.5128$; $\nu = 57.3$; $n_F - n_C = 0.00894$; $n_D - n_{A'} = 0.00575$; $n_F - n_D = 0.00630$; $n_{G'} - n_F = 0.00508$. The ratio $(n_D - n_{A'}) / (n_{G'} - n_F) = 1.132$. From figure 4 we find that glass No. 45, a dense barium crown, has approximately the same ratio between the two partial dispersions, namely, $(n_D - n_{A'}) / (n_{G'} - n_F) = 1.127$. Its optical constants are: $n_D = 1.6098$; $\nu = 58.8$; $n_F - n_C = 0.01037$; $n_D - n_{A'} = 0.00665$; $n_F - n_D = 0.00730$; $n_{G'} - n_F = 0.00590$. The partial dispersion ratios for the two glasses are:

| No. | $\frac{n_D - n_{A'}}{n_F - n_C}$ | $\frac{n_F - n_D}{n_F - n_C}$ | $\frac{n_{G'} - n_F}{n_F - n_C}$ |
|-----|----------------------------------|-------------------------------|----------------------------------|
| 26 | 0.641 | 0.704 | 0.569 |
| 45 | .642 | .704 | .569 |

From the analyses of these two glasses it is not a difficult matter to write down appropriate batches. Thus the batch for the

zinc silicate crown, No. 26, is approximately sand 100, zinc oxide 17.0, sodium carbonate (Na_2CO_3) 34.0, and sodium nitrate (NaNO_3) 11.3. A suitable first trial batch for the glass No. 46 is sand 100, boric acid (B(OH)_3) 69.5, alumina (Al_2O_3) 25.7, barium carbonate (BaCO_3) 199.5, arsenious oxide 3.0. The function of the alumina in this batch is to lessen the tendency of the barium oxide to form crystallization nuclei of barium disilicate and also to improve the working qualities of the melt itself.

From diagram 4 we note that a third glass, namely, the barium crown, No. 27, has almost the same dispersion relations; its ratio $(n_D - n_{A'}) / (n_G - n_F)$ is 1.132. Its partial dispersion ratios are 0.640, 0.703, and 0.565 for the intervals D to A' , F to D , and G' to F , compared with the mean dispersion for the interval F to C . From analysis 27 a first trial batch composition may be computed by the methods outlined and found to be: sand 100, boric acid B(OH)_3 9.0, zinc oxide 8.4, barium carbonate 41.7, sodium carbonate 9.0, potassium carbonate 18.5, potassium nitrate 9.5, arsenious oxide 0.5. The addition of more barium carbonate to this batch would raise the refractive index. As the amount of BaO is raised, that of the alkalis is lowered in order partly to reduce the corrosive action of the melt on the pot.

These examples suffice to indicate that the problem of batch compositions of optical glasses is one of interpolation, together with a certain amount of experience which enables the glass-maker to determine what the behavior of the melt will be and other questions of a similar kind. In all cases it is advisable to prepare small charge melts, 5 to 50 kilograms in weight, to stir these properly, and to ascertain on the finished glass its optical constants. Good quality glass can not be attained by this procedure and the conditions are distinctly different from those in the melt of a large charge of 500 to 1000 kilograms; but the order of magnitude of the optical constants obtained is correct. It is also advisable to hold the small charge melt for a relatively long period of time at temperatures somewhat below the final stirring temperatures in order to ascertain the tendency of the melt to crystallize or to become milky and opalescent; the batch can then be modified accordingly.

It may be of interest to note that this part of the general prob-

lem of optical glass manufacture proved, during the war, to be one of the least of our troubles and indicated the futility of secrecy in this particular phase of optical glass manufacture. As a research problem, the general task of optical glass manufacture in war time differs from ordinary research problems because the properties of the final product are definitely known and the task is to reproduce glasses of known characteristics rather than to develop new types of glasses.

Summary

The manufacture of optical glass as a war-time problem required the solution of many different problems in order to establish it on a definite basis of routine quantity-production. One of these problems was the development of suitable batches for the several types of optical glasses needed in military optical instruments. This necessitated a detailed study of the relations between chemical compositions and optical constants of glasses and of the factors, such as volatilization, pot solution, state of annealing, which tend to change the relations during the manufacture of the glass. The amount of accurate information available at the time, especially of a chemical nature, was meager, but exceedingly valuable to us. The problem was accordingly attacked by graphical methods and solved sufficiently to enable us to write down the approximately correct batches for the types of glass which were urgently required. A few experimental melts enabled us then to correct for errors arising from selective volatilization and the like, and thus to set up satisfactory batch compositions.

In this paper the several factors involved are presented chiefly in graphical form; the dispersion relations alone are first considered, after which the chemical characteristics and the relations between chemical composition and optical constants are treated in summarized diagrams to indicate the methods which we adopted and which enabled us to solve the problems in a practical way in a short time. No consideration is given to the more fundamental problem of computing the optical constants of a glass of given

chemical composition.¹ The information at hand was not adequate for this purpose and our war-time interest was not concerned with this problem which still awaits satisfactory solution.

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NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor*

¹ The first five papers of a series of articles on "The development of various types of glasses" have recently been published by C. J. Peddle in *Jour. Soc. Glass Technology*, 4, 3-107 (1920); see also "The optical properties of some lime-soda glasses," by J. R. Clark and W. E. S. Turner, *Jour. Soc. Glass Technology*, 4, 111-115 (1920).

THE CONSTRUCTION OF A NOVEL TESTING FURNACE¹

By S. F. WALTON

In constructing a furnace for testing ceramic products, it was decided to avail ourselves of the down-draft principle so as to protect the head of the testing machine from heat. It is, primarily, as the cut shows, constructed of fire-brick. The base contains the cross flue, the center well hole and the main flue to the chimney. Above this base a circular wall was formed of segmental circular brick $4 \times 4 \times 1\frac{1}{2}$ inches with $10\frac{1}{2}$ -inch radius. These brick were made in the laboratory of a special highly refractory silicon carbide mix. Back of this wall is an inch and half of "Sil-o-Cel" tamped in place, and a four and a half inch wall of circle fire clay brick. On account of limited space the chimney or stack had to be built into the wall of the furnace. The floor between the flue openings was built of silicon carbide refractory, to resist impact, and the circular muffle, which is in two halves, is of similar material. The knife edges, on which the test pieces for cross breaking are set, are shown inside of this muffle. They are placed 6 inches center to center. The ports for the gas burners were set tangential to the circular wall and were formed of galvanized iron. Fire clay was packed around these except where it passed through the inner wall where silicon carbide cement was used. As the metal burnt away it left the refractory material baked in shape, and no cracks have developed.

The position of the furnace made it necessary to build a long flue from the top of the chimney proper to connect with the flue of a muffle furnace and out to the main stack. This flue is of some interest as it is constructed by placing a five inch galvanized iron pipe inside of a seven-inch and filling the annular space with Johns-Manville No. 26 refractory cement. The inside pipe has burnt out in places but the cement has set firm. The result is a flue which withstands the high temperature of our exit gases and yet is of simple and inexpensive construction.

¹ Received Feb. 27, 1920.

To use this furnace for cross-breaking tests (it is obvious that it is not limited to that use alone) a lever arrangement was set up as is shown in the second cut. A six-inch I-beam *A* is supported on knife edges in the stand *B*. The lever ratio is one to two. The knife edge of the refractory pressure block *E* is centered on the test piece, the latter resting on the knife edges bedded into the floor of the furnace as previously described. These

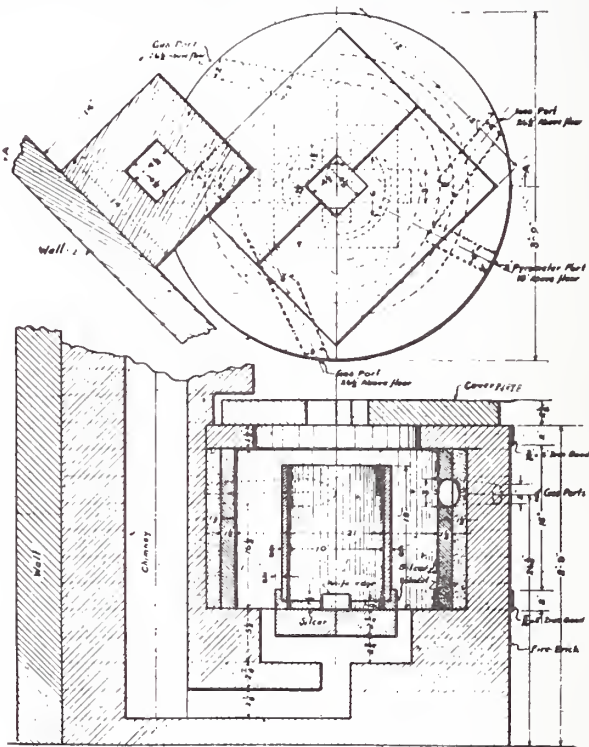


FIG. 1.—Test furnace.

knife edges, and the pressure block, were made of a special high grade silicon carbide refractory. The pressure block fits into a recess in the head *I*, which is suspended on steel knife edges. A similar head is at the other end of the *I* beam. A chain jack *C*, which has a handle fastened to the sprocket wheel, is set on the platform scale *D* with the plate in the recess of the head.

A Mariotte's bottle *G* and a bucket *H* hung from the balance arm of the platform scale complete the equipment,

The operation is as follows: The test piece, preferably $2 \times 2 \times 8$ inches, is set on the knife edges and the pressure block set on top with its knife edge centered. The gas is lighted and the temperature brought up to 1000°C in four hours. A time-temperature curve is plotted by means of a noble metal thermocouple set within a half inch of the test piece, which records on a Leeds and Northrup curve drawing potentiometer. After holding for twenty minutes at the required temperature to allow even distribution of heat the load is gradually applied.

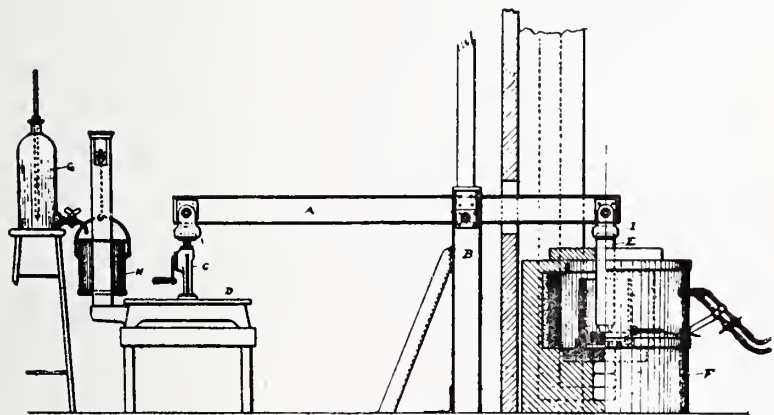


FIG. 2.—Test furnace layout.

The system has meanwhile been balanced so that the scale balance arm is horizontal. Water running into the bucket *H* continuously disturbs this balance which is continually renewed by screwing up the jack. The water is allowed to run in at a uniform rate sufficient to increase the load by 80 pounds per minute. The load is increased until rupture takes place. The ratio of the levers on the platform scale is one to one hundred and the ratio of load in the bucket to the load applied on the test piece is then one to two hundred.

At the moment of rupture the supply of water is shut off and the amount in the bucket weighed. Two hundred times this

plus the weight of the pressure block gives the load applied. This amount is substituted for P in the formula $\frac{3}{2} \frac{Pl}{bd^2} = \text{modulus of rupture}$.

The data required in each case is the cross section, width, and depth of the piece, appearance of fracture and the total time in minutes of applying the load. The latter is simply a check on the rate of increase of load. By use of a Mariotte's bottle the flow of water was practically constant. This method of applying the load is much more satisfactory than the use of shot.

The whole apparatus is much simpler than any I have seen discussed in the Transactions or the Journal, and for the comparison of refractory materials which are to be used where the modulus of rupture is an effective criterion, it is very satisfactory.

It might be of interest in closing to say that a refractory we have developed has shown a modulus of rupture of 5000 pounds at 1000°C . Another interesting fact is that certain classes of refractory showed 25 per cent to 35 per cent greater strength at 1000°C than at room temperatures.

By the use of a premixing device recently installed we are able to obtain a temperature of 1450°C with gas, and the apparatus can be used at, and withstands, this temperature satisfactorily.

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NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor*

THE RATE OF VITRIFICATION OF PORCELAIN MOLDED UNDER DIFFERENT CONDITIONS,^{1,2}

BY R. F. SHERWOOD

It is a well known fact to ceramists that the initial structure of a clay body governs, to a certain extent, the rate of contraction and vitrification. Thus it might be expected that a dry pressed body will vitrify at a different rate than one which has been molded by hand or cast. Although some numerical data are available, particularly with reference to the dry or semi-dry pressing process, there is still lack of information on this important subject.

In the present work it was endeavored to show the difference in the rate of vitrification of one and the same body, molded by hand pressing in the plastic state, by casting and by dry pressing at different pressures, and finally fired simultaneously in the same kiln, and hence subject to identical heat treatment.

The composition of the porcelain body was as follows:

| | |
|--------------------------------|-----|
| Feldspar..... | 22% |
| Flint..... | 31 |
| Tennessee ball clay No. 5..... | 12 |
| English china clay..... | 25 |
| Florida kaolin..... | 10 |

This mixture was made up into briquettes about $2 \times 1 \times 1$ inch, by three processes, pressing in the plastic state by hand, using a plaster mold, casting in a similar mold, with the use of 0.2 per cent of sodium silicate and sodium carbonate, and pressing in a steel mold at the pressures of 2,000, 4,000 and 6,000 pounds per square inch. The pressure was obtained on an Olsen testing machine set to exert the required load.

The water content of the dry pressed specimens was between 6-7 per cent, except with E, where it was only 1.12 per cent.

The weights of the pieces in the dried state were 1.67 grams per cubic centimeter for the body molded in the plastic state,

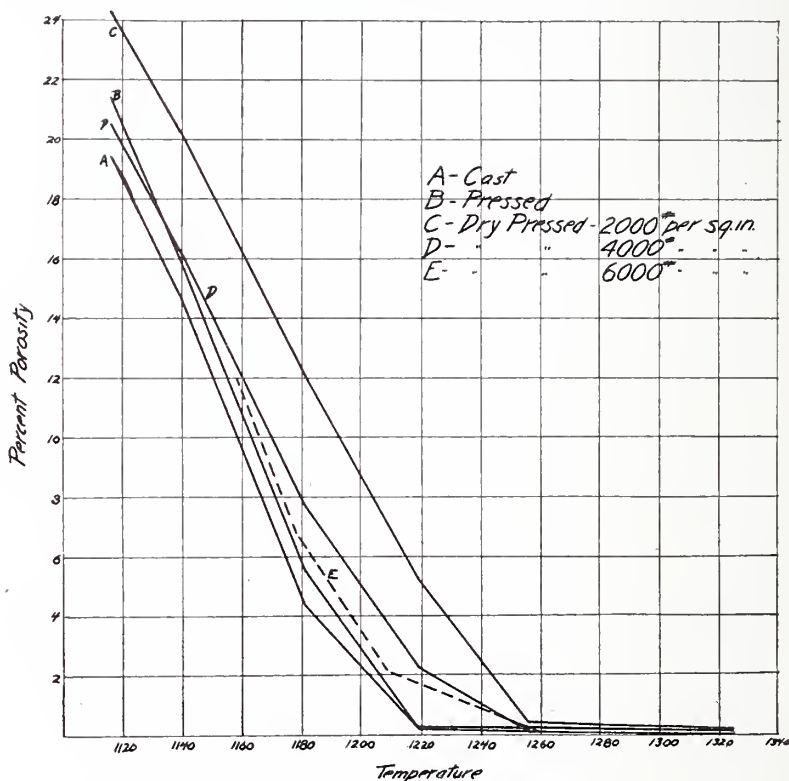
¹ Received Feb. 27, 1920.

² By permission of the Director, Bureau of Standards.

1.76 grams for the cast, 1.71 grams pressed at 2,000, 1.73 grams pressed at 4,000, and 1.78 grams pressed at 6,000 pounds per square inch.

The densest mass is thus produced by dry-pressing at 6,000 pounds per square inch, followed by the casting process, dry pressing at the lower pressures, and finally by molding in the plastic state.

The briquettes, after thorough drying, were fired in a large test kiln with a temperature increase of 20°C per hour, above



800°C , under conditions accurately controlled by pyrometer measurements and the use of cones.

At regular intervals three of each kind of trial pieces were withdrawn from the kiln in the customary manner. The speci-

mens pressed at 6,000 pounds per square inch were fired in a different burn and hence were subjected to slightly different conditions.

The porosity of the briquettes was determined in the usual manner. The results correlating these values with the temperatures are shown graphically on the accompanying diagram.

The curves show that down to a certain point, say a porosity of 2 per cent, the mean rate of vitrification is greatest for the body molded in the plastic state, followed in order by the cast and dry-pressed specimens, the lowest rate being shown as is to be expected by the one pressed at the lowest pressure. By mean rate of vitrification is meant the drop in porosity corresponding to a definite increase in temperature, or the differential of the curve, $\frac{dy}{dx}$, expressed by its tangent, it being assumed that the relation is a linear one. These values then would be as follows:

| | |
|-------------------------------|-------|
| A. Cast body..... | 0.200 |
| B. Plastic molded..... | .214 |
| C. Dry pressed, 2000 lbs..... | .174 |
| D. Dry pressed, 4000 lbs..... | .171 |
| E. Dry pressed, 6000 lbs..... | .174 |

The point corresponding to two per cent porosity is reached by the different specimens at the following temperatures:

| | |
|-------------------------------|----------|
| A. Cast body..... | 1202° C. |
| B. Plastic pressed..... | 1206 |
| C. Dry pressed, 2000 lbs..... | 1243 |
| D. Dry pressed, 4000 lbs..... | 1223 |
| E. Dry pressed, 6000 lbs..... | 1210 |

Minimum porosity, close to vitrification, is reached with the several methods of molding, as follows:

| | |
|-------------------------------|----------|
| A. Cast..... | 1219° C. |
| B. Plastic pressed..... | 1219 |
| C. Dry pressed, 2000 lbs..... | 1256 |
| D. Dry pressed, 4000 lbs..... | 1255 |
| E. Dry pressed, 6000 lbs..... | 1255 |

From the data obtained it appears, first, that the initial structure of the body dry-pressed at 6,000 pounds per square inch is

most dense and that of the plastic material least so. At 1120°C the initial porosity is lowest in the case of the cast body and greatest for dry pressing at the least pressure. The porosity of the material pressed in the plastic state occupies an intermediate position.

Second, the rate of vitrification is most rapid for the plastically molded body, followed by the cast material. The rate of condensation for the dry-pressed body is markedly slower though it seems that greater pressure accelerates the vitrification process. There appears to be a distinct difference in heat effect when comparing the wet-molded with the dry-pressed material and probably also greater heat absorption. There appears to be little difference between the heat behavior of the cast as against the plastic pressed body though some distinction is discernible and it is reasonable to assume that more heat units will be absorbed in bringing about equivalent changes of unit mass of the cast than with the plastic pressed material.

Third, for a given degree of porosity not too far removed from complete vitrification the cast body reaches such a point at the lowest and the dry-pressed material at higher temperatures, according to the pressure applied. The temperature difference between the extremes is about 40°C , roughly equivalent to two cones.

Fourth, minimum porosity is reached practically simultaneously by the cast and plastic pressed body and also simultaneously by the body molded at the pressures of 4,000 and 6,000 pounds per square inch. The one pressed at 2,000 pounds shows a slight lag.

Fifth, complete vitrification indicated by zero apparent porosity is not reached at the maximum temperature employed, 1325°C , by the body molded in the plastic state nor by the one subjected to dry pressing at 2,000 pounds. It is attained by the material molded by the other processes. It would seem, therefore, that the degree of compactness governs also the temperature at which complete vitrification takes place or the time during which a given temperature must be maintained.

Discussion

MR. GEORGE SIMCOE.—How was the power applied in the case of the 6,000 pound pressure dust pressed sample, continuously or intermittently, giving the clay a chance to free itself of air? Our experience in the manufacture of dust-pressed ware requires us to air the piece, as we term it; that is, apply a slight pressure at first then relieve the same. In some instances we use the foot treadle to bring the piece above the top of the die so that the sides may have a chance to permit the air to go out. Otherwise the piece is liable to have laminations which occur at right angles to the direction of the power applied.

AUTHOR'S REPLY.—The pressure on the die was applied very slowly, by an Olsen testing machine. Hence it was unnecessary to air the piece to prevent laminations, because of the pressure being applied much more slowly than in the manufacture of dust-pressed ware. However, the trials that contained but two per cent of water when they were pressed were found to crack very slightly when fired to cone 14. In the case of the other trials no laminations were found.

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OIL FIRING OF KILNS*

BY F. A. WHITAKER

During the latter part of 1919, we conducted a series of tests in the burning of chemical stoneware, using fuel oil in place of gas coal.

It was our intention to simplify the present complicated burning process and, if possible, lessen the cost of this operation and at the same time make ourselves independent of the coal supply which is at present very irregular both as to quantity and quality.

To this end, we equipped one of our small kilns with a low-pressure fuel-oil equipment furnished by a firm prominent in this line of work. The kiln used in these tests was rectangular in shape, measuring about $12 \times 12 \times 8$ feet high inside. It was of the open fire, down-draught type, furnished with four fire holes, two on each side.

The oil used was Western, light in contrast to the heavy Mexican oil, which is used for other purposes. For these tests, we arranged for a temporary gravity feed and the necessary air was carried through a 4-inch galvanized pipe line from the blower at a pressure of about four pounds.

On each of the four fire holes of the kiln, we placed two $1\frac{1}{4}$ -inch burners in the combustion chamber proper, and in the ash pit $\frac{3}{4}$ -inch burners, the grate bars, of course, having been removed. The reason for this was that we wanted to start with a very small flame, and we expected trouble in keeping the larger burners lit if turned very low.

No change was made in the design of the fire boxes except that the grate and cross bars supporting these were removed and the front of the fire hole was bricked up, leaving just a small slit for the flame from the burners to enter. The flames impinged upon a special carborundum block which distributed the fire into the combustion chamber in a fan shape.

At the commencement of the burn, two of the small burners were started in diagonally opposite corners and about six hours

* Received February 27, 1920.

later, the other two small burners were started. These burners were gradually opened until after 25 hours' firing, the interior of the kiln commenced to get red. When the small burners had developed their maximum heat, they were shut off and the larger burners put into operation and finally we had all eight burners going at the same time.

On this first test, we found it impossible to mature the ware at the bottom of the kiln, although the upper part was nicely finished, and so on the next test we used 2-inch burners for finishing instead of 1½-inch and improved the results considerably. Our main trouble, however, remained, *i. e.*, that there was a considerable drop in temperature from the fire box to the bottom of the kiln, and it would have been impossible to mature the latter without overfiring the top and probably burning out the fire box lining. This convinced us that the type of burner we were using was not satisfactory for the purpose and subsequent conversations with other parties using fuel oil, showed us that this was undoubtedly the case.

Unfortunately we were not able to make more than three trial burns, owing to the difficulty in procuring the necessary oil, but the experience we had, convinced us that although the actual cost in fuel consumed was considerably higher than when using gas coal, the ease in control and consequent possibility, up to a certain extent, of standardizing the burning process convinced the writer that this method of firing would have big advantages in the firing of such complicated material as chemical stoneware.

In conclusion, I would state that we had no difficulty in closely controlling the advance in temperature or composition of the fire gases, and our only trouble lay in attempting to get an even distribution of the heat and a long flame, which could undoubtedly be overcome by finding the right type of burner.

We had no difficulty in salt glazing the ware. For this purpose, we constructed a special injector which blew the salt into the combustion chamber in a fine stream with the help of compressed air.

· DISCUSSION

MR. D. W. ROSS: The gentleman said he did not want the firing to be at the mercy of the foreman in charge. On the Pacific Coast several concerns were using oil in burning hollow ware. It gave the fireman a tremendous weapon, because he could go to pretty near any temperature he wanted, and it was easy for him to melt down the top five or six course of hollow ware and then wake up an hour or two later and find out what he had done. The oil could supply such a tremendous heat in such a short time that, although it was nice to work with, it was very dangerous with workmen who were not very reliable.

MR. A. P. GORTON: The whole matter was threshed out quite a number of years ago in 1892, by Thomas Gray, a New England potter, and the various devices he had to resort to are well described in our Transactions, Volume XV, page 661. I think every one attempting to use oil for the first time has about the same experience, the concentration of heat in the firing box and the difficulty in communicating that heat to the interior of the kiln. I might say that we have used fuel oil during the winter in firing tank block kilns, and we believe with considerable success. In firing time, we have effected a saving of at least two days over firing with coal, and this saving has been accomplished mostly by the fact that with oil we can effect a regular progression in the time temperature curve. I would like to ask Mr. Whitaker in this connection what was used to spray the oil, that is, whether steam or air, and under what pressure, since that has a lot to do with the results obtained? We started to use high pressure air, at about 75 pounds, and had this trouble of the fire box getting enormously hot. The trouble was overcome to a great extent by the substitution of steam at 80 pounds, and we found that the fire box was much cooler and the combustion projected more into the kiln. We have also tried this same method on our continuous tunnel kiln at Carbon, Mo., in the burning of high grade fire brick, and have had just as much success there. As to the expense, it is very nearly as cheap as burning coal in the solid condition.

PROF. C. F. BINNS: If the members will turn to volume 1 of the Transactions of the American Ceramic Society, they will

find this subject discussed by Stanley G. Burt. He raised this very point. He stated that in order to get cone 5 in the kiln he had to reach nearly cone 25 at the burner, and he came to the Society at that first meeting to find how to get over the trouble.

MR. D. H. APPLGATE, JR.: The difficulty which most people get into in substituting oil for coal fuel is that they attempt to put the oil flame into the coal fire box without other changes than to cover the grates with fire brick and to brick up part of the door space. This is a great mistake.

The coal fire box is necessarily deep to allow for the fuel bed and combustion space above it. With an oil fire this provides a large combustion chamber close to the burner and causes an intense heat to be developed at that point. This burns out the fire box and produces a condition of constantly diminishing temperature as the gases diffuse throughout the kiln and advance toward the exit.

A properly designed oil furnace should be approximately funnel shaped with the small end next to the burner and with the bottom sweeping on an easy curve into the bag. The cross-sectional area of the furnace should be slightly less than that of the bag at the junction of the two. This will provide for the expansion of the flame as it proceeds, but will confine it without undue restriction at any point and will cause it to maintain its velocity and carry well into the kiln before combustion is entirely completed. It is possible to make the flame extend to the bottom of the kiln and still have good combustion conditions.

To adapt a coal furnace to oil burning, the bed should be built up with fire brick and covered with fire sand so that it will slope slightly upward from the mouth toward the bag wall and will join the latter in an easy curve which should become tangent to it. The distance from the bed to the edge of the fire arch at its highest point should be 1 to $1\frac{1}{2}$ times the width of the bag, depending on the spread of the flame. The latter should be so directed as to be close to the sand bed of the furnace and to avoid direct contact with the arch.

My experience agrees with that of Doctor Gorton in that steam at not less than 60 pounds pressure is a better atomizing agent than compressed air for producing an even temperature

throughout the kiln, but steam to be successfully used for this purpose must be superheated, and the superheating furnace should be close to the burners. The use of too much or too wet steam will, however, cause a waste of oil as it forms a large volume of inert gas which must be heated and passed through the kiln. To overcome this tendency I tried forcing air under slight pressure from a blower through a longitudinal slot in the bed of the furnace directly under the path of the flame. That relieved the burner from the necessity of forcing the full requirement of air into the furnace and so saved much steam. It effected a saving of about 15 per cent in the oil consumed and still gave the advantage of the steam in producing a long easy flame. A considerable part of the air is carried under the flame and does not completely combine with it until well into the kiln.

There was much less wear on the fire boxes in this method of burning than when coal was used and there was little difficulty in getting an even heat throughout the kiln. I have burned kilns of brick in this way with a difference of less than two cones between the top of the setting next to the crown and the course next to the floor.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

CERAMIC ABSTRACTS¹

General

The electro-osmotic process in ceramics. F. SINGER. *Berichte der Technisch-wissenschaftlichen Abteilung des Verbandes keramischer Gewerke in Deutschland*, 5, 16-23 (1919).—A thorough refining is not obtained by the older methods of refining kaolins since the specific gravities of many of the impurities is almost the same as that of kaolin and hence the finer impurities are not removed by gravity methods. In the electro osmotic process a predetermined weight of electrolyte is added to the slip and the impurities such as quartz, spar, iron pyrites and mica settle to some extent while the clay with the finer impurities remain in suspension. The electric current is then turned on and the electro negative clay is attracted to the anode while the positive impurities are repelled to the cathode. The water content of purified kaolin is 30-35% while that of plastic clays is 15-25%. Tostmann found that where kaolin is washed in the ordinary method he was continually troubled with spots and flaws in cast ware, whereas ware cast with electro-osmosed clay was perfect. This is probably due to the freedom from fine mica in the osmosed clay.

H. G. SCHURECHT.

The properties of some stoneware clays. H. G. SCHURECHT. *Tech. Paper*, 233, U. S. Bureau of Mine, 1920, 42 pp., 1 pl. and 23 figs. See *Jour. Amer. Ceram. Soc.*, 1, 267-286 (1918).

H. G. SCHURECHT.

A new process of centrifugal filtration. W. G. GEE. *J. Soc. Chem. Ind.*, 39, 301-2T (1920).—This article describes the construction of a centrifugal filter of the solid drum type having as a new feature a removable lining. The solid material is deposited in a layer on this lining and then the lining is elevated from the drum and the solids are quickly removed. The removal of the recovered solids is said to require much less time than the cleaning of a filter press and the cleaning of filter cloths.

A. J. LAMBERT.

The physical properties of stoneware glazes. R. RIEKE. *Berichte der Technisch-wissenschaftlichen Abteilung des Verbandes keramische Gewerke*, 5, 8-15 (1919).—In general it might be said that crazing of glazes is due to a difference in the coef. of expans. of the glaze and body. Although a high elasticity and tensile strength may prevent crazing where the expansion of the body and glaze are different, such glazes are not very durable as they often craze after a long time. For hard burned porcelains and porcelain glazes the expansion increases uniformly with an increase in temp. The coefs.

¹ The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of Chemical Abstracts by coöperative agreement.

of expans. of Berlin tech. porcelain at 700°C . is 35.10^{-7} while porcelain glazes vary from 27.10^{-7} to 42.10^{-7} . It is possible therefore to pick glazes which have the same coef. of expans. as the porcelain. With stoneware it is impossible to get a glaze which expands and contracts the same as the body since stoneware bodies always contain considerable free silica. Cristobalite has a sudden change in volume at 200°C . Since even low melting glazes are no longer soft at 200°C ., the stoneware in contracting suddenly at 200°C . in cooling causes cracks in the body or glaze. Furthermore with glazes which harden above 500°C ., strains are produced due to the conversion of α to β quartz at 575°C . The coef. of washed kaolin is about 40.10^{-7} to 80.10^{-7} . A stoneware containing 25 per cent flint and fired at cone 7 had a coef. of expans. of 130.10^{-7} between 15°C . and 200°C ., 70.10^{-7} between 200°C . and 500°C ., 140.10^{-7} between 500°C . and 600°C . and 50.10^{-7} between 600°C . and 1000°C . The coef. of expans. of stoneware glazes varies between 57.10^{-7} and 96.10^{-7} . It is therefore impossible to fit a glaze to a stoneware body with such varying expansions. The mod. of elast. of a glaze varies between 5700 to 6800 kg./sq. mm. which is a very small range. It may be said therefore that the coef. expans. of glazes may be varied between comparatively wide limits by means of their chemical composition but the mod. of elast. can be varied but slightly by this method. The tens. strength of the majority of stoneware glazes probably lie between 5 to 8 kg./sq. mm. although some lie as low as 3.5 kg./sq. mm. Of the above properties the coef. of expans. is the most important. The tens. strength is more important than the mod. of elast. For ex. if two glazes have a mod. of elast. of 5000 and 7000 kgs./sq. mm. respectively and a tens. strength of 5 kg./sq. mm. a rod 10 cm. long would be expanded 0.10 mm. and 0.07 mm. respectively with a tension of 5 kg./sq. mm. If the tens. strength is 8 kgs./sq. mm. and the maximum tension applied the expansion would be 0.17 mm. and 0.11 mm. respectively for the glazes with different mod. of elast.

H. G. SCHURECHT.

Surface combustion. A. E. BLAKE. *Proc. Eng. Soc. Western Pa.*, **36**, 145-204 (1920).—This term was originally used for the catalytic action of metals and later non-metallic refractories upon homogeneous, explosive gas mixts. B. applies it to a flameless, complete, and exceedingly rapid oxidation, attained in a special design of furnace. This involves the use of a perfect mixt. whose advantages are (1) the release of total available energy; (2) a minimum reaction vol., giving max. heat concn. and max. temp.; (3) an instantaneous combustion leaving max. time for heat transfer before products of combustion reach flue; (4) the smallness of reaction zone, avoiding danger of injury to work and permitting smaller furnace design and (5) the superior radiation of incandescent material over more or less sooty flame. Among the disadvantages of an imperfect mixt. are the loss of energy absorbed by inactive air, slowing down of reaction due to diln., and detrimental effect of oxidizing atms. within the furnace. The original underfired-refractory type of furnace caused great trouble in keeping the ports open, but now an inclined

tube projects the perfect mixt. into a pocketed bed of refractory, which becomes incandescent. A higher temp. is permissible here than the furnace lining could stand. In another type the mixt. is delivered from a nozzle to the base of a refractory-lined tunnel, which acquires incandescence and effects complete combustion rapidly. Of most importance is the production of a perfect or const. mixt., which is done by low- or high-pressure automatic devices on the Venturi principle. Once set, it will deliver const. proportions throughout the range of the app. Accompanying illustrations present examples of furnace engineering in the industrial applications of surface combustion; very remarkable results in steam generation have been attained in England. A bibliography is appended. In discussion, considerable attention was given to refractories, the practicability of remodelling furnaces for surface combustion, the failure of the present 2-valve control, and the fact that no claim can be made of originality in the use of a perfect mixt.

[C. A.]

PATENTS

Kiln. CHARLES E. CARPENTER. U. S. 1,349,185, Aug. 10, 1920. A kiln bottom comprising a pair of crossed flues communicating with each other at their point of intersection, one of the flues being open at the top to communication with the interior of the kiln and one end of the other flue forming an outlet to a stack. An annular flue intersects and communicates with the crossed flues and is open at the top to communication with the interior of the kiln.

Drier-tray. CARL EDWARD JOHNSON. U. S. 1,349,458, Aug. 10, 1920. This describes a tray made from angle strips in such a manner that the angle irons form U-shaped channels for the passage of hot air.

Non-metallic resistance element and process of making same. ALEXANDER L. FEILD. U. S. 1,349,053, Aug. 10, 1920. An electric resistance element containing a compound of a metal of the titanium-zirconium group, and a refractory oxide, the element having a substantially zero temperature resistance coefficient.

Drier. JOHN O. TENSFELDT. U. S. 1,349,590, Aug. 17, 1920. A drier comprising a chamber having mounted therein: a drying chamber, a distributor of heated air, and a chamber beneath said drying chamber adapted to receive moistened air from the same. The drier has means connected therewith for circulating the air through the chamber, extracting the moisture from the air, and heating the air. The distributor comprises a longitudinal channel and a plurality of side channels arranged at intervals and provided with perforations in the bottom whereby the heated air is delivered at intervals and in a downward direction.

Pot-furnace. ELMER L. KNOEDLER. U. S. 1,349,159, Aug. 10, 1920. A pot furnace, comprising a tiltable pot, means whereby heat may be applied-

thereto, and stirring means mounted on the pot to rotate therein about an axis which is at an angle to the tilting axis of the pot. C. M. SAEGER, JR.

Artificial stone. H. GRÖNROOS. Brit. 138,799, June 4, 1919. Nearly equal parts of porcelain or faience refuse, powdered pipeclay, and crushed glass are mixed together with a little H_2O and poured into a mold the bottom of which is covered with crushed glass. Pressure of about 2850 lb. per sq. in. is applied and the material is then exposed to a temp. of 900–1200° to produce an artificial stone or marble-like slab having a glazed surface. Variegated effects are produced by using glass of various colors. Cf. C. A. 14, 2249. [C. A.]

Drying china-clay. J. ADAIR. Brit. 142,161, Dec. 16, 1918. An app. comprizes a combination of mechanical loading-app., drying-floors with heating means, and means connected with the floors for unloading the dried clay from the floors. The settling-tank is formed with inclined bottom parts leading to an inclined central channel which is fitted with a worm or chain-scraper to discharge the clay into a receiver, from which it is delivered by an elevator to a travelling tray or hopper above the drying floors. The hopper is mounted upon wheels and has bottom parts which open downward to allow the clay to fall on to the floors. The drying floors or trays may be stationary or travelling on wheels, and their bottom parts flat or corrugated. A suitable construction is specified. [C. A.]

Refractories

Transverse strength of fire clay tile. Bur. of Standards, *Tech. News Bull.*, 40 (1920). Anonymous.—A number of tests have just been completed on fire clay tile subjected to a temperature of 1350° C. in order to determine the modulus of rupture and the deformation. The surprising fact was brought out that these tiles, in spite of their weight and bulk, can not support any appreciable load beyond their own weight, and in the case of long spans it was found that the tiles broke without any imposed load. It is quite possible that for load-carrying refractories of this type, entirely different compositions and combinations of clay and grog must be resorted to. A. J. LAMBERT.

Carborundum coating for fire-brick. P. M. GREMPE. *Brit. Clayworker*, 29, 113 (1920).—G. in the Jour. für Gasbeleuchtung discusses the use of carborundum as a coating for refractory brick. It has been found that, with a sufficient coating, the fire-brick need not be so refractory. Seventy-five per cent carborundum and 25 per cent water glass make an excellent coating. If fire brick are basic 85 per cent carborundum and 15 per cent clay may be used. The brick should be thoroughly dry before the coating is applied a layer of 0.02 in. is thick enough for even the highest temps. The coating is allowed to dry 24 hrs. and then is heated up very slowly. The coating becomes burned into the brick and there is left a firmly adherent glassy coating of carborundum which resists mechanical injury and shelters the fire brick

from the chem. action of the flames. The coating is remarkably insensitive to sudden temp. changes. The coating can be applied to every part of a producer, including firebars. A half years working with daily heating and cooling did not injure the lining in the least. Gas retorts have their life increased by coating them inside and out. Cracks in retorts can be promptly repaired by a mixture of 50 carborundum and 50 clay, worked up with water, even when the retort is hot.

H. G. SCHURECHT.

Refractories for the glass industry. Bur. of Standards, *Tech. News Bull.* 40 (1920). Anonymous.—The Bureau has commenced an investigation having for its object the development of improved refractories out of which to construct pots, and so forth, for the glass industry with particular reference to their resistance to corrosion. The principle adopted has been to systematically study such bodies composed of siliceous bond clays mixed with aluminous grog and of aluminous bond with siliceous grog. A large number of crucibles have already been made from these mixtures. These will be subjected to the action of a corrosive barium glass. Upon breaking the crucibles, the depth of penetration and degree of attack of the glass upon the material of the crucible will be determined. In addition, the transverse strength of the mixture, both in the dried and in the fired state, as well as the shrinkage will be measured.

A. J. LAMBERT.

Investigation of combination of aluminous and siliceous bond clays used in making of crucibles. Bur. of Standards, *Tech. News Bull.* 40 (1920). Anonymous.—The search begun during the war for American clays to replace German clays in making crucibles and glass pots is now being extended and will soon be completed. Small pots have been made from various combinations of aluminous and siliceous bond clays and will be subjected to the corrosive action of various kinds of glasses. It has been found that when used with 50 per cent grog, Arkansas kaolin has even a lower shrinkage and higher porosity than the famous German Gross Almerode clay.

A. J. LAMBERT.

PATENTS

Refractory substances. G. I. DIMITRI. Brit. 142,512, May 1, 1920. Natural Mg silicates such as talc, steatite, Briancon chalk, are mixed in a powdered state with a flux consisting of natural or artificial multiple silicates such as feldspars, mica pyroxene or the like or with rocks containing them, as granite, gneiss, porphyry, pegmatite. The mixt. is prepd. moist or in powder form, dried, shaped, and burned at about 1450° to produce refractory and elec. insulating articles.

[C. A.]

Lining retorts and furnaces. S. A. McMINN. Brit. 137,419, Feb. 28, 1919. A mixt. contg. 30 per cent or more of powdered glass, together with fire-clay, such as Stourbridge or china clay, or a clay contg. over 90 per cent SiO₂ is used as a glazing-cement for lining retorts or furnaces. A mixt. of china clay with SiO₂ clay and ground glass in equal proportions may be employed. Cf. C. A. 14, 2247.

[C. A.]

Glass

The glass melting furnace. ANON. *Glasindustrie*, **31**, 97-8, 105-6(1920).—**Pot Furnaces.** The Siemens furnace, with regenerators beneath the furnace is typical of the regenerative type. The Nehse and Siebert furnaces are typical of the recuperative type. The Siemens furnace now costs 12-15000; the Siebert 10-12000 and the Nehse, 9-10000 marks. Checker brick are usually $250 \times 120 \times 65$ mm. or $250 \times 80 \times 80$ mm. and space between bricks is 60-80 mm. Bricks should not be over 80 mm. thick. Ironing of the furnace is one of the most important points in construction. The advantages claimed for tanks are (1) greater production, (2) economy of fuel, (3) freedom from delays with pots, (4) use of lower alkali and therefore cheaper glass mixtures, (5) less skill required in operation. The regenerative type tanks are the Siemens, Gobbe, Henning and Wrede and Klattenhoff. The recuperative type tanks are the Nehse, Dralle and the Nehse-Dralle. Approximate costs are given for various constructions. C. H. KERR.

The manufacture of especially pure sodium sulfate for use in the production of highest grade crystal glass. K. KILLER. *Sprechsaal*, **53**, 93-4(1920).—Ordinary salt cake used in the glass industry contains about 1 per cent SO_3 , 0.5 per cent NaCl and 0.07-0.13 per cent Fe_2O_3 . A specially pure sulfate from Knothe and Fritsche, Bodenback, showed 99.72 per cent Na_2SO_4 , 0.08 per cent NaCl and 0.0009 per cent Fe_2O_3 . C. H. KERR.

The common processes of decorating glass. CARL JUNG. *Sprechsaal*, **53**, 107-8, 119-20, 129-31, 138-41, 145-7 (1920).—The decoration is as old as the making of glass. The various processes are described in considerable detail under the headings: (1) those caused by manipulation of the glass batch; (2) soft glasses with suitable furnace treatment. These fall into 3 classes: (a) by fashioning, (b) by a layer of other glass on the hot glass body, (c) by other means; (3) those applied to cold glass and (4) combinations of (1)-(3). Many details are given. C. H. KERR.

Measurements of the thermal dilatation of glass at high temperatures. C. G. PETERS AND C. H. CRAGOE. Bur. of Standards, *Sci. Paper* **393** (1920).—The methods and results of an investigation of the thermal expansion and the chemical composition of different kinds of optical glass, chemical glassware, and commercial tubing are presented in this paper. A ring of the glass, placed between two fused quartz plates, was heated in an electric furnace and its expansion measured by the Fizeau interference method. Observations were made in the temperature regions between 20° and 650° C. on 32 different kinds of glass. Their dimensional changes are represented by curves which show that the glass passes through a critical expansion region, in which the expansion rate increases by 2 to 7 times. This critical region, which for any one glass does not exceed 40° , was found as low as 400° C. with one glass and as high as 575° C. with another. About 75°

above the critical region the glass softens and contracts. A comparison of results shows that the heat absorption observed by Tool and Valasek occurs in the same temperature region as the critical change in the expansion.

A. J. LAMBERT

Glass for pressed ware. ANON. *Glasindustrie*, 31, 81-2(1920). The glass must not lose its fire polish during pressing. As a rule about 3-5 kg. KNO_3 per 100 SiO_2 is required to make the glass workable. Good formulas are:

| | Crystal | Clear | Grayish | Rose red | Turquoise blue | Milk white |
|--------------------------------|---------|-------|---------|----------|----------------|------------|
| Sand..... | 100 | 100 | 100 | 100 | 100 | 100 |
| K_2CO_3 | 12 | 15 | 5 | 10 | 40 | 10 |
| Na_2CO_3 | 23 | 17 | 30 | 24 | ... | 15 |
| CaCO_3 | 14 | 13 | 14 | 11 | ... | 13 |
| Pb_3O_4 | 5 | ... | ... | ... | 3 | ... |
| KNO_3 | 5 | 2 | 3 | 3 | 4 | 5 |
| As_2O_3 | 0.5 | ... | ... | ... | ... | ... |
| NiO | ... | 0.003 | 0.003 | ... | ... | ... |
| Witherite..... | ... | ... | ... | 24 | ... | ... |
| Gold..... | ... | ... | ... | 0.005 | ... | ... |
| Bone ash..... | ... | ... | ... | ... | 7 | ... |
| Asbestos..... | ... | ... | ... | ... | 4 | ... |
| CuSO_4 | ... | ... | ... | ... | $1\frac{1}{2}$ | ... |
| Cryolite..... | ... | ... | ... | ... | ... | 15 |

C. H. KERR.

Bottle glass. ANON. *Glasindustrie*, 31, 89-90(1920).—Twelve formulae are given for white, green, blue-green, brown and yellow glasses.

C. H. KERR.

Plate glass. ANON. *Glasindustrie*, 31, 89 (1920).—Nine formulae for plate glass and window glass are given, including formulae for aquamarine blue and antique green.

C. H. KERR.

Practical developments with substitutes in glass decoration. ANON. *Glasindustrie*, 31, 73-4 (1920).—A much wider use of sand-blasting, staining and paper decoration has resulted from war conditions.

C. H. KERR.

PATENTS

Apparatus for drawing glass sheets. HALBERT K. HITCHCOCK. U. S. 1,349,201, Aug. 10, 1920. A container for glass approximating in length the width of the glass sheet to be produced and comprising side and end walls downwardly and inwardly inclined, and heating chambers along the side walls only.

Means for transferring hot glass. MICHAEL J. OWENS. U. S. 1,350,464, Aug. 24, 1920. An apparatus with a trough, means to deliver hot glass

thereto, and means to revolve the trough about an axis extending lengthwise of the trough.

Glass-working machine. EDWARD MILLER. U. S. 1,350,375, Aug. 24, 1920. The combination with a movable table, molds comprising relatively movable parts carried by the table, a reciprocal table actuator, a primary air valve shifted by the actuator, a pneumatically operated secondary air valve controlled by the primary air valve, air-pressure motors controlled by the secondary valve, and connections between said air-pressure motors and the molds.

Glass-gathering mechanism. AUGUST KADOW. U. S. 1,350,552, Aug. 24, 1920. This describes an apparatus for manufacturing glass, with the combination of a vessel to contain molten glass, gathering mechanism and means for moving the same over the glass in the vessel. This mechanism comprises a gathering mold, an oscillatable elbow-shaped supporting device for the mold, means for oscillating the same while the gathering mechanism is over the vessel so as to bring the gathering end of the mold into and out of contact with the glass. The mold comprises separable elements, and means for opening and closing the same.

Apparatus for conveying molten glass. JOSEPH B. GRAHAM. U. S. 1,350,448, Aug. 24, 1920. This apparatus has means for discharging molten glass, and a switch device comprising a plurality of means for receiving and directing the glass to different positions. The receiving and directing means are brought individually into operative position by the movement of the switch, the latter having an intermediate position permitting the glass to be discharged independently of the receiving and directing means.

Sand and slime separator. JAMES D. McDONALD. U. S. 1,350,509, Aug. 24, 1920. In a slime and sand separator, the combination with a casing having an inlet at one end, a slime outlet at the other end, and a sand outlet at one side. An outer reel is rotatably mounted within the casing and has blades moving past said sand outlet, and an inner reel is mounted within the outer reel and rotates in the opposite direction, both reels having skeleton heads.

Glass-feeding machine and process. KARL E. PEILER. U. S. 1,349,551, Aug. 10, 1920. The combination with a container for molten glass having a discharge outlet, of supporting means beneath the outlet adapted to suspend discharged masses of the glass, and means for periodically tilting said supporting means to time the formation of suspended masses. The method of separating molten glass into mold charges which consists in flowing the glass onto a support, periodically tilting the support to form successive gathers of the glass suspended from the support, and severing a mold charge from each gather.

C. M. SAEGER, JR.

Lamp shades, and so forth; silvering; varnish. E. M. BENNETT. Brit. 137,887, Jan. 2, 1919. A reflecting lamp shade or globe of transparent glass has its outer surface silvered or otherwise provided with a reflecting surface, and its inner surface formed with integral projections to refract and distribute the reflected rays. The projections may be of pyramidal, diamond, or jewel shape and have flat, concave, or convex sides. The reflecting medium is covered with a protective coating such as elastic varnish composed of 10 parts dammar gum, 3 parts asphalt, 5 parts gutta-percha, and 75 parts benzene. A suitable silvering compn. is made from 175 grs. AgNO_3 and 10 oz. distd. H_2O , 262 grs. NH_4NO_3 , and 10 oz. of distd. H_2O , 50 grs. tartaric acid dissolved and boiled for 10 min., and, when cool, added to 1 oz. alc. and distd. H_2O sufficient to make up 10 oz. Equal parts of the ingredients are mixed together and the shade or globe, after being cleansed, is suspended outer-face downwards in the liquid for 20 to 80 min. [C. A.]

Whiteware and Porcelain

The mechanical properties of ceramic bodies and exact testing methods of same. E. ROSENTHAL. *Berichte der Technisch-wissenschaftlichen Abteilung des Verbandes keramischer Gewerke in Deutschland*, 5, 23-33(1919).—The mechanical strength of ceramic wares is important not only for technical porcelain but also for a large number of other wares, such as hotel ware, table porcelain, stoneware and electrical porcelain. Considerable has been published on the tens. strength, compress. strength and cross bending strength but little has been done to meas. the resistance of ceramic wares to impact and torsion. The compress. strength of porcelain is about 4000 kg./sq. cm., tens. strength is 140-160 kg./sq. cm. and cross bending strength is about 500 kg./sq. cm. A weight suspended as a pendulum is used to meas. the resistance to impact. An apparatus used to meas. the torsion of ceramic bodies is described. H. G. SCHURECHT.

Porcelain token money. ANON. *Chem. Met. Eng.*, 23, 297 (1920).—The city of Meissen and other towns have ordered porcelain coins for local use to solve the small-change scarcity and obviate the present unclean and easily tearable paper currency. Germany is said to be about to introduce porcelain small-change coins. A. J. LAMBERT.

Enamels

The relation of composition to the softening point of enamels. Bur. of Standards, *Tech. News Bull* 40 (1920). Anonymous.—The Bureau has undertaken a study of the relation of composition to the softening point of enamels. From the data obtained so far it may be stated that the effect of various constituents on the softening point is not in accord with the chemical similarity of these constituents. For instance, certain basic oxides act as refractories in enamels, while others act as fluxes. The same is true for the so-called intermediate oxides and the acid oxides. In a given chemical group

of oxides the fluxing effect is not in proportion to the molecular weight, and on the other hand equal percentage amounts of the various oxides do not have the same fluxing effect. The action of each oxide and mineral used in compounding enamels seems to be characteristic of that particular mineral or oxide and can not be calculated by any system of *a priori* reasoning.

A. J. LAMBERT.

Fish scaling of sheet steel enamels. Bur. of Standards, *Tech. News Bull.* 41 (1920). Anonymous.—As one phase of a comprehensive investigation of this subject, the relation of cold-working of the steel, such as is undergone by steel shapes which are pressed into form before enameling has been studied. It has been found in a number of cases that stretching the steel eliminated fish scaling which had occurred on unstretched steel of the same lot. These results confirm the observations made in practice that those parts of vessels which have been spun or stretched in shaping are often free from fish scaling in enamel, while the parts that have not been stretched contain fish scales.

A. J. LAMBERT.

Relation of composition of enamel to solubility in acids. Bur. of Standards, *Tech. News Bull.* 41 (1920). Anonymous.—During the progress of this investigation, it was noticed that in a large number of cases enamels scratched to some extent after being subjected to the action of boiling acid for only a few hours but after continued treatment would not scratch at all. This led to the conclusion that possibly the boiling acid had some annealing effect upon the enameled surface that made it more resistant. It has been found that boiling enamels in oil for several hours before subjecting them to the acid treatment entirely eliminated this preliminary scratching and softening of the surface. Boiling in water had a similar but not as great an effect as boiling in oil, while simply heating the pieces in air had little effect. It would seem advisable to treat with boiling oils all enameled wares which are to be subjected to the action of corrosive liquids.

A. J. LAMBERT.

Brick and Tile

Some brick-iron problems. J. Scott. *Brit. Clayworker*, 29, 114-115 (1920).—Although 5 per cent ferric oxide in some clays does not yield a striking redness in some clays, 3 per cent of it in others will often give a pronounced red. In the clay from which buff-colored brick are prepared the iron is often present as pyrites, *i. e.*, iron sulphide or disulphide. The richer a clay is in alumina the more likely it is to burn off buff rather than red. If sufficient chalk or lime is mixed with an ordinary red burning clay, the brick from it, when fired below 800° C. remain red; but when fired above this temp. the chalk reacts with the lime making the brick buff. When buff brick are examined under the microscope the pigments have the appearance of magnetic iron oxide.

H. G. SCHURECHT.

Paving-brick and method of making the same. FRANK W. WOOD. U. S. 1,350,764, Aug. 24, 1920. A paving brick having projections on its side with each projection surrounded by a recess extending into the body of the brick at the base. The method of forming paving brick with projections on the side which consists in first forming the brick and then subjecting them to a re-pressing operation under a die having depressions surrounded by projecting cup-shaped rims.

Paving. NORTON CO. Brit. 138,865, Jan. 24, 1920. A non-slipping paving or tread consists of cryst. grains of a hardness of 9 or more, such as corundum, emery, fused Al_2O_3 , SiC , and so forth, bonded into chips $\frac{1}{4}$ -2 in. in size by a ceramic material, the chips being embedded in cement, asphalt, and so forth, to form a surface-layer. The ceramic material consists of 44 parts by wt. of slip clay, 44 parts of feldspar, and 12 parts of ball clay. The ingredients are crushed, mixed dry with the crystals, damped and pressed into lumps, and fired at about 1300° for 50 to 100 hr., then cooled slowly and crushed to size. The foundation may be formed by excavating, laying crushed stone and adding successive layers of stone and cement to form the bed. The matrix for the top layer may consist of hydraulic or Mg oxychloride cement, or resinous or bituminous material. Cf. C. A. 14, 2065. [C. A.]

Abrasives

PATENTS

Abrasives. N. C. HARRISON. Brit. 137,490, July 14, 1919. An abrasive is made by fusing in the elec. furnace calcined diaspor, Fe such as ground cast-iron borings, and coke, preferably in the proportions of 17:2:3, and cooling slowly with or without agitation. It consists of corundum with some ferrosilicon; no slag is formed. [C. A.]

Cement and Lime

Colored plasters. Bur. of Standards, *Tech. News Bull.* 41, (1920). Anonymous.—It has been found possible to make colored wall plasters of any desired color or texture by use of dyed wood fiber in gypsum plaster. Panels of this material have been submitted to the Gypsum Industries Association in Chicago, and a publication on the subject is now being prepared.

A. J. LAMBERT.

Utilization of low-grade fuel and increased efficiency in portland cement manufacture. ANON. *Chem. Age (N. Y.)* 28, 205-7 (1920).—By a recent invention of Robert W. Lesley (cf. C. A. 14, 330) oil shale, lignite, low-grade bituminous and cannel coal, and so forth, can be used as fuels in the manuf. of portland cement, and at a considerable saving. The low-grade fuels are destructively distd. in retorts, the retorts being placed between the rear end of the rotary kiln and the flue. The kiln gases pass off at 1000° - 1400° F., while the

temps. required for the distn. of the fuels referred to above, range from 800° F. for light oils to 1300° F. for heavy oils. The oil and $(\text{NH}_4)_2\text{SO}_4$ resulting from the distn. are recovered as usual, the gas is carried to the front end of the kiln and used as fuel while the coke residue, which is usually high in ash, is conveyed to the kiln hopper and fed in with the other cement raw materials. The C content of the coke aids in the combustion within the kiln, while the ash, which is usually argillaceous, produces good clinker after it has been mixed in the kiln feed hopper with the proper amt. of calcareous material. The distn. retorts do not interfere with the recovering of potash from the spent flue gases.

[C. A.]

ACTIVITIES OF THE SOCIETY

Important Actions of the Board of Trustees at the Chicago Meeting, August 16, 1920

It was voted to raise the price of a complete set of the Transactions to \$150.00, subject to 40% discount to members. Five sets are to be reserved for disposal by vote of the Board of Trustees only.

It was voted to hold the 1921 Annual Meeting in Columbus, and Professor A. S. Watts was appointed chairman of the local committee.

Mr. F. H. Riddle was appointed a committee to draw up a code of ethics covering the relationship between the ceramic engineer and the owner of the factory, with regard to the patenting of ceramic formulas, and so forth.

Mr. H. F. Staley's resignation as Editor of the Journal was received, and his offer to retain the position if necessary until the beginning of the new year was accepted.

New Members Received during September

Resident Associate

Adams, Lewis A., Mansfield, Ohio, Superintendent, Mansfield Vitreous Enameling Company.

Fitz-Gerald, Gerald, Muncie, Indiana, Maxon Furnace and Engineering Company.

Gassman, H. M., 848 Brown-Marx Bldg., Birmingham, Ala., Consulting Engineer.

Legg, Victor E., 330 Vinewood Ave., Detroit, Mich., Research Physicist, Detroit Edison Company.

Marshall, P. M., 195 Broadway, New York City, Purchase Engineer, Western Electric Company, Inc.

Mitscherling, W. O., Ph.D., Landing, N. J., Atlas Powder Company.

Nolan, C. J., Toledo, Ohio, General Manager, Modern Glass Company.

O'Hara, Eliot, 46 Greenwood Lane, Waltham, Mass., Manager, O'Hara Waltham Dial Company.

Ragland, Nugent A., 1006 S. 5th Street, Champaign, Ill.

Richardson, P. B., 1018 Marine Trust Bldg., Buffalo, N. Y., Salesman, Harbison-Walker Refractories Company.

Roberts, Frank G., Baltimore, Md., Service Engineer, Porcelain Enamel and Manufacturing Company.

Schramm, Edward, 574 Whittier Ave., Syracuse, N. Y., Research Chemist, Onondaga Pottery Company.

Stover, J. Homer, 176 Grant Ave., Nutley, N. J., Sales Manager, John Johnson Company, Brooklyn, N. Y.

Wright, Marcus S., South River, N. J., Miner and Shipper, Foundry Sands and Clay.

Foreign Associate

Bateson, H. A., Liverpool, England, Glass Bottle Manufacturer.

Fogelberg, Sven, Kosta, Sweden, Assistant to Direktor, Kosta Glass Works.

Gass, George P., "The Hollins," The Haulgh, Bolton, England, Director, Entwish & Gass, Ltd.

Gregg, Henry, Knottingley, England, Gregg & Company.

Orrell, John, Thorold, Ont., Canada, or Pilkington Bros.

Rees, W. J., 102 Ivy Park Rd., Ranmoor, Sheffield, England, Head of Refractories Research Dept., University of Sheffield.

Shibata, R., 41 Kaminku, Tokyo, Japan, Professor, Higher Technical School.

Snowdon, William C., 24 Beaconsfield St., Acomb, York, England.

The Entertainment of the Ladies at the Next Convention

The entertainment of the ladies who will attend the next annual convention in Columbus, Ohio, February 21 to 24, 1921, has been placed in charge of Mrs. Arthur S. Watts, 1764 North High St., Columbus, Ohio.

Mrs. Watts has announced her intention of making this a feature of the coming convention and desires to get into communication with every lady who hopes to attend the convention whether she has made definite plans to do so or not.

If you have never taken your wife to an American Ceramic Society Convention, you have missed a source of real pleasure both to her and yourself.

The ladies should communicate with Mrs. Watts at the earliest possible moment so that a suitable program may be provided.

The Society at the Chemical Exposition

Was it worth while for the American Ceramic Society to maintain a booth at the Chemical Exposition?

One hundred and twenty-seven names on the register, sixty-five members and guests at the luncheon, nine hundred booklets and a hundred and fifty copies of the Journal distributed, fifty catalogs of the ceramic schools given out before the week was half over—these facts will furnish an answer. In addition, many inquiries about the Society and the schools were answered, technical questions were referred to the proper authorities, and headquarters service was rendered as far as possible.

Interest among the general public was aroused by means of a small exhibit of bone china, loaned by Lenox, Inc., a number of aventurine vases by Mr. Minton, some decorated ware loaned by Roessler and Hasslacher Chemical Company, and a model of a nitric acid plant, loaned by the General Ceramics Company. The Transactions and Journal of the Society, with its other publications, and photographs and literature from the various ceramic schools were also exhibited and created opportunities for publicity.

Ceramic Day, Friday the 24th, was well attended. The luncheon held at the Hotel Commodore was a real success, and an interesting program was presented in the afternoon, consisting of the following papers:

"The Potter's Art and the Chemist's Science," R. H. Minton.

"Decorative Architecture," Leon V. Solon.

"The Influence of the Artist in Industrial Ceramics," J. Munro Hewlett.

"Report of the Committee on the Definition of 'Ceramic'," read by Charles F. Binns.

"A Classification of Sheet Steel Enamels," R. R. Danielson.

"Possibilities for Research and Development in the Field of Refractories," H. F. Staley.

The contributions by Mr. Solon and Mr. Hewlett aroused much interest because they differed from the papers and addresses which have hitherto formed the bulk of the Society's literature, both dealing with certain phases of art work. Mr. Hewlett, a prominent architect, advanced the theory that the manufacturers of clay wares, notably terra cotta, should show more initiative in the leading of public taste. This aroused some discussion, and it was pointed out that the manufacturers are, to a large extent, obliged to obey the specifications of the architect. The other papers were also of high grade.

In the evening a number of industrial moving pictures were shown, among them one on the manufacture of pottery, loaned by the Rookwood Pottery. A film on the manufacture of electric lamp bulbs, loaned by the Nela Park Laboratories, arrived too late for the program.

The ceramic industry was well represented at the Exposition. The exhibits of chemical stoneware, chemical porcelain, glass, enameled iron, kilns, dryers, furnaces, pyrometers, and other equipment attracted favorable comment.

CHAS. F. BINNS, *Secretary*

Meeting of the Northern Ohio Section

The tenth meeting of the Section was held in Elyria, Ohio, October 4th. An early start was made to the plant of The Elyria Enameled Products Company, who are manufacturers of steel and cast iron enameled apparatus for the dairy, canning and chemical industries. All details of the plant were carefully explained and an inspection of the new ceramic and chemical engineering laboratories was made.

Lunch was served at the Y. M. C. A., at which we were guests of the Elyria Enameled Products Company. After lunch a business session was held and the following technical program was submitted:

"Technical Control and Research in an Enameling Plant," B. A. Rice, Ceramic Chemist, Elyria Enameled Products Company.

In this paper the detail involving plant control was outlined and those present interested in this line of work could appreciate the efforts of the writer.

"The Uses of Enameled Apparatus," Max Donauer, Sales Chemist, Elyria Enameled Products Company.

In this paper it was plain to be seen that this company tries to anticipate the use of their product and then watches the abuse to which it is subjected.

"The Development of the Enameling Industry during the Last Fifteen Years," R. D. Landrum, Service Manager, Harshaw, Fuller & Goodwin Co., Cleveland.

This subject was ably presented by the author, who was one of the very first to specialize in enameling research and has extensively published papers on this subject.

"The Refractory Problems of the Enameling Industry," E. P. Poste, Chemical Engineer, Elyria Enameled Products Co.

Mr. Poste gave an extemporaneous talk on refractories from live items in his note book and many could realize the grief almost every manufacturer has who is dependent upon any great amount of heat for results.

We were privileged to have with us for the day Mr. Homer F. Staley who kindly responded to a request for a speech. His closing remarks were an appeal for every member to hustle advertising for the Journal.

CHARLES H. STONE, JR., *Secretary*

JOURNAL

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EDITORIAL

SOME WAR DEVELOPMENTS IN GERMANY

If necessity is the mother of invention, war can well be said to be the father. The war has brought highly changed conditions to the ceramic industry in Germany. Before the war the white-ware industries used Swedish or Norwegian spars and flints and English ball clays and china clays. With the cessation of importation of English clays it was necessary to find substitutes, particularly for such products as sanitary ware and electrical porcelains, which can not afford the expensive clays used in the dinner ware industry. Since the war the low exchange has made it almost prohibitive to import any of these raw materials, and great efforts are being made to entirely substitute the domestic, or the Austrian materials. To a great extent these efforts have been successful, although accompanied by the trials and losses which are always encountered in making substitutions of raw materials.

Perhaps the most adverse influences of the war on ceramic productions have been from the coal shortage. Many plants, including the former Royal Works at both Berlin and Dresden, are burning successfully with wood. To burn to cone 14 with wood requires courage, entirely aside from the difficulty and expense. The supply of coal is now greatly restricted and the ceramic industry not only has reduced allotments but the most inferior qualities. Many plants are operated with brickettes having a heating value of two thousand calories, and with brown

coal, which has the appearance of being only rotten wood, with the value of only two thousand calories, as against the normal coal of seven thousand calories.

Much has been printed about the paper suits of Germany but nothing about the paper belts which are of real commercial value. These are made in the link type and in the woven fabric type similar to canvas belts and are said to give excellent satisfaction. Belts are in operation which have been exceedingly satisfactory from the standpoint of wear and of traction, as there is less slipping on the pulleys than with ordinary canvas belts, and their life is as long.

An interesting development has been the production of laboratory crucibles and other articles from pure Al_2O_3 , MgO and ZrO_2 . These are made in various sizes and shapes for high temperature work and have been very useful. The Al_2O_3 and the MgO vessels will stand a temperature of 1900°C . and the ZrO_2 of 2000°C .

During the war the supply of materials for the manufacture of dynamite was exhausted and liquid air was substituted. The ingenuity of the German technical ceramist is shown in production of double-walled vacuum vessels for transporting and using the liquid air. Liquid air was kept at a temperature of 110°C , and was used largely in coal mining. A tube of peat, or other absorbing materials, was placed in the bore hole and the liquid air poured into it until saturated and then exploded by electric spark. Vessels of two or three gallons capacity were made for transporting the liquid air and smaller ones for handling in using. Liquid air was introduced and the vessel sealed by a blowpipe and not opened until ready for use. These vessels were made of hard porcelain and were absolutely impervious.

ORIGINAL PAPERS AND DISCUSSIONS

HEAT TRANSMISSION OF BRICK AND HIGH TEMPERATURE INSULATING MATERIALS*

By ROY A. HORNING

It is the purpose of this paper to discuss briefly the methods of making transmission tests and the heat transmission of various kinds of brick and insulating material.

Transmission tests have been made in most every conceivable way, but they are all based on one of three things or a combination of them. It is known that heat can travel in only three ways, radiation, convection, and by conduction. Radiation and convection apply, of course, only to gases and liquids. Conduction applies to solids, although it is possible that the conductivity of porous material is affected by the convection of the enclosed air and the radiation from wall to wall of the air cells.

Two general methods of making transmission tests are employed, the hot-box method and the hot-plate method. In the hot-box method the heat is dissipated to the air in the box, the air carries it by convection to the inner surface of the box, here it is absorbed, transmitted and dissipated to the external air by radiation and convection. By the use of this method it is possible to obtain three factors concerning the material: First, the surface absorption; second, the internal conduction; third, the radiation.

Owing to the fact that there is no way to measure accurately the convection of the air, the radiation factor and the surface absorption factor would be very inaccurate. If the temperatures of the surfaces are measured accurately, the conductivity factor would be fairly accurate. This method is slow, cumbersome, and at its best is inaccurate, owing to the difficulty of maintaining a uniform temperature all over the surfaces.

* Received February 27, 1920.

In the hot-plate method a heated surface is applied directly to the material. The heat may be supplied by hot liquids, air, or direct heating by electricity. This does not matter; the chief requirement for a method to fall in the hot plate class is in that the heat is applied directly by contact to the surface of the material.

The most ordinary hot plate method is to use a flat heating plate, interposing it between two layers of the material, each having the same dimensions. The whole is raised off the floor by supports, allowing a free circulation of air, or by placing cooling plates on the top and bottom. The surface may be maintained at a uniform temperature by the use of brine, water or oil.

Apparatus

The method used in making tests to determine the figures on heat transmission by the author is a slight modification of the method just described. The hot-plate method is subject to errors from several sources, the chief one, however, is what is known as the edge loss, or the heat dissipated from the edge of the block. On a 20-inch square block two and one-half inches thick, there would be a loss back $2\frac{1}{2}$ inches from the edge; or on 43 per cent of the area edge loss would occur to a greater or less degree.

To overcome the error and also to bring the error in measuring the surface temperatures to a narrow limit, we arranged to measure only a portion of the heat transmitted over the entire area. In making the tests only the heat dissipated on the center one-ninth of the area exposed to the heating element is considered. This area can be considered as being insulated with material at the same temperature and its area accurately measured. There would be no lateral flow of heat since a difference in temperature is required for a flow of heat. We assume that all heat dissipated over this area is transmitted at right angles to the hot plate. We have made tests to find the variation in temperature on this area and have found no variation that can be measured by the ordinary pyrometer.

The sketch (figure 1) shows the arrangement of the testing unit, its dimensions and the position of the instruments used

in taking measurements. The cooling plates are made of cast iron in two sections. These plates have baffles cast in them, compelling the water to flow across zigzag the plate. The surface placed on the material under test is machined down to $\frac{1}{16}$ inch thickness and painted a dead black so as to absorb the heat.

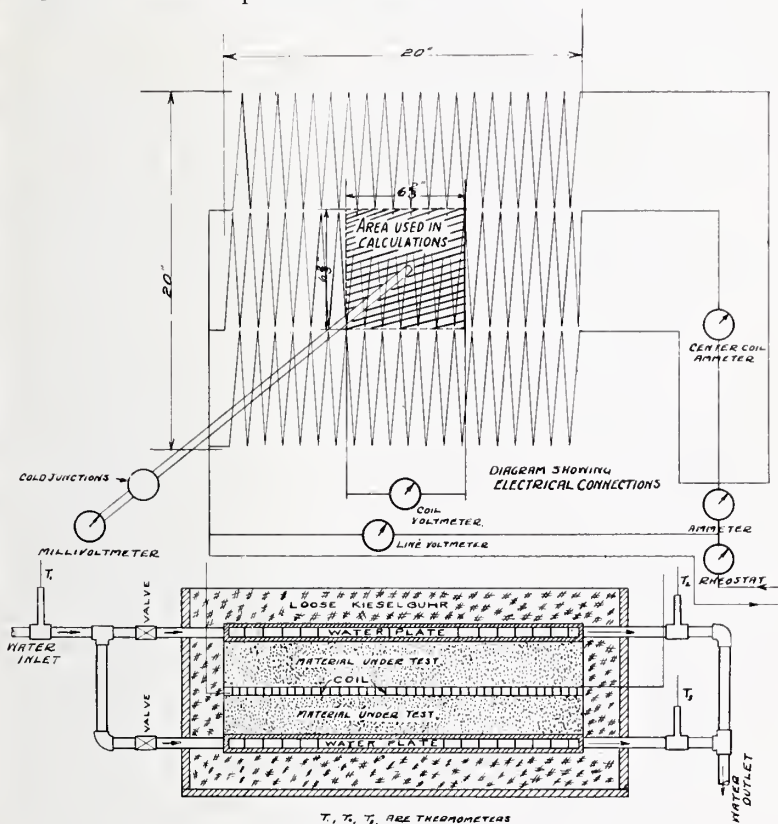


Fig. 1.—Apparatus for making hot plate tests.

The heating element is composed of three similar coils, made from No. 26, $\frac{3}{8}$ inch resistance ribbon, such as nichrome. These coils are made the same length and are connected in parallel. The instruments required are one volt meter, an ammeter, a millivolt meter, 1 thermocouple, and three thermometers which read accurately.

Calculations

The data secured are:

1. Voltage drop across the length of coil used in heating the area over which measurements are to be taken.
2. Amperage through the center coil. (The amperage through this coil will not be one-third of the total, as the center coil may be hotter than the other two.)
3. The temperature of the surface of the material exposed to the coil. (This is obtained by embedding the junction in the surface of the material.)
4. The temperature of the water entering and leaving. (The average of these temperatures give the average temperature on the external surface of the material.)

The calculations are as follows:

Heat dissipated per hour:

V (voltage drop on coil) $\times A$ (amperage of center coil) $\times 3.416$.
There are 3.416 B. t. u. in 1 Watt flowing 1 hour.

Heat transmission, as used in this paper, is the amount of heat transmitted per 24 hours, per square foot of area, per °F difference in temperature (between hot and cold surfaces) per 1 inch of thickness, or

$$\text{Transmission} = \frac{V \times A \times 3.416 \times 24 \times (\text{thickness in inches})}{(\text{area sq. ft.}) \times (\text{dif. in temp.})}$$

Example:

| | |
|---|-------|
| Voltage drop through center $\frac{1}{3}$ of center coil..... | 10 |
| Amperage in center coil..... | 10 |
| Area in sq. ft..... | 0.888 |
| Thickness in inches..... | 2 |
| Difference in temperature..... | 500 |

$$\text{Transmission} = \frac{10 \times 10 \times 24 \times 3.416 \times 2}{0.888 \times 500} = 36.92 \text{ B. T. U.}$$

The hot plate can be used for making a heat balance, in such a way that three checks are given on the heat transmitted.

1. By measuring the rise in temperature of the water and taking the weight of the water passing through the plate during a certain length of time. The heat absorbed would, of course, be the heat transmitted.

2. By taking the total heat dissipated over the entire area and calculating the transmission on this basis.

3. By the method described previously, using the heat dissipated over the center, one-ninth of the total area.

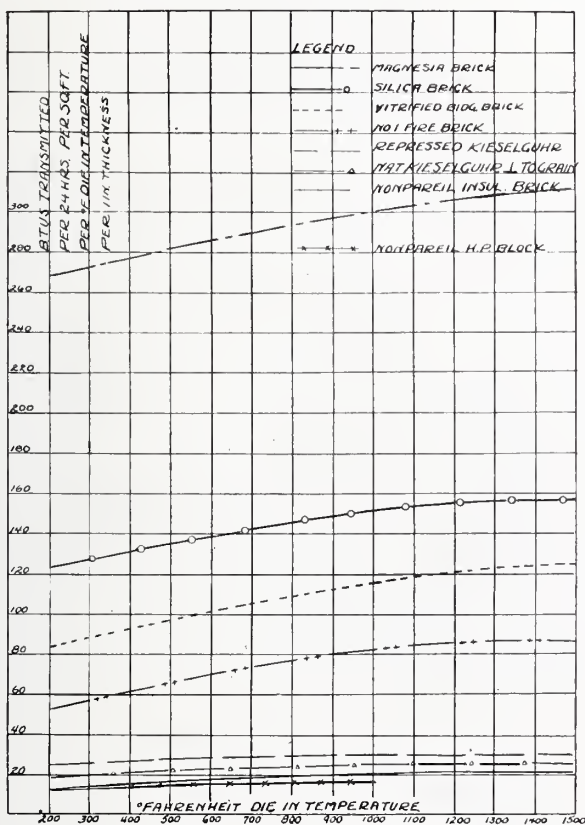


FIG. 2.

The errors that appear in these ways are:

1. Edge loss, radiation loss, error in weighing and measuring the temperature of the water.
2. Edge loss, error in getting an even temperature over the entire area.
3. Slight error in measuring the temperature of the two surfaces.

From a study of the curves (figure 2) and the table the actual and the relative transmission of various materials can be determined.

One feature of the hot-plate method is that the surface resistance is automatically combined in the transmission figures. In the way in which insulating material and brick are used, both surfaces are usually covered with brick or plaster so that their transmission is a resultant of the surface resistances and their internal conductivity.

In making use of the figures given here to determine the heat losses through a wall, first select the strata of material on which you desire to make the determination, drill two holes, one running to the outer surface and one to the inner surface of this strata. By placing thermocouples in these holes the drop in temperature can be measured; the distance apart, of course, can be measured. By consulting the curves, the heat lost can be determined. For example, a wall consists of 9 inches No. 1 fire-brick and 9 inches of common brick. Drill two holes, one 17½ inches in depth, one 14 inches in depth. The holes would be 3½ inches apart and in the same material. The drop in temperature would be, say 300 degrees F. Consulting the chart we find that the transmission for 300 degrees F difference in temperature for No. 1 fire-brick, is 57 B. T. U. per degree difference per sq. ft. per one inch thickness. In this case the thickness is 3½ inches. The heat transmitted per square foot per 24 hours in this case would be approximately

$$\frac{300 \times 57}{3.5} = 4885 \text{ B. T. U.}$$

Continuous Transmission Determinations

It is a well known fact that the transmission even with the same difference in temperature changes rapidly. That is to say, the transmission which is determined for a difference of 200° F, between 400° F and 600° F is not the same as it would be if the 200° difference existed between 800° F and 1000° F. So far as the writer knows there has been no satisfactory method of determining the transmission for a certain difference in temperature, and following the difference between two low temperatures up to the higher temperatures.

HEAT TRANSMISSION TABLE

B. T. U's. Transmitted per 24 hrs. per sq. ft. per °F dif. in temp. per 1 in. thickness

| Material | Cubic Foot wt. lbs. | Degrees Fahrenheit dif. in temperature | | | | | | | | | | | | | | |
|---|------------------------|--|------|------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|--|
| | | 200° | 300° | 400° | 500° | 600° | 700° | 800° | 900° | 1000° | 1100° | 1200° | 1300° | 1400° | 1500° | |
| Magnesia brick..... | 164.0 | 268 | 273 | 276 | 280 | 284 | 288 | 292 | 296 | 300 | 302 | 305 | 307 | 309 | 310 | |
| Silica brick..... | 97.0 | 123 | 127 | 132 | 136 | 139 | 142 | 145 | 148 | 151 | 153 | 154 | 156 | 158 | 159 | |
| Vitrified bldg. brick | 133.0 | 84 | 89 | 92 | 97 | 102 | 105 | 110 | 113 | 116 | 119 | 121 | 123 | 124 | 125 | |
| No. 1 fire-brick..... | 131.0 | 52 | 57 | 62 | 66 | 70 | 74 | 77 | 81 | 83 | 85 | 86.5 | 87.0 | 87.5 | 87.5 | |
| Repressed, burned kieselguhr brick..... | 23.2 | 24.0 | 25.0 | 26.0 | 26.0 | 26.5 | 27.0 | 27.5 | 27.7 | 28.0 | 28.1 | 28.2 | 28.5 | 28.5 | 28.5 | |
| Natural kieselguhr brick, 1 to grain.... | 33.0 | 19.9 | 20.0 | 20.5 | 21.0 | 21.5 | 21.9 | 22.3 | 22.7 | 23.1 | 23.5 | 23.9 | 24.3 | 24.7 | 25.2 | |
| Nonpareil insulating brick..... | 24.0 | 13.0 | 14.4 | 15.6 | 16.8 | 17.8 | 18.8 | 19.6 | 20.1 | 20.6 | 21.0 | 21.4 | 21.7 | 22.0 | 22.2 | |
| Nonpareil high pressure bl'k..... | 21.2 | 13.5 | 14.0 | 14.5 | 15.0 | 15.5 | 16.0 | 16.5 | 17.0 | 17.6 | ... | ... | ... | ... | ... | |

Figure 3 shows an apparatus designed for this purpose. The idea is to heat both surfaces until there is a certain difference in temperature, then to raise the temperature simultaneously on both sides of the material. A constant difference in temperature can be maintained in this manner and studied from low temperatures to high temperatures. The details of the apparatus are as follows:

B , Electric coil on which measurements are made—figure 4.

A_1 , A_2 , Electric coils which are used to heat exterior of material under test—figure 5.

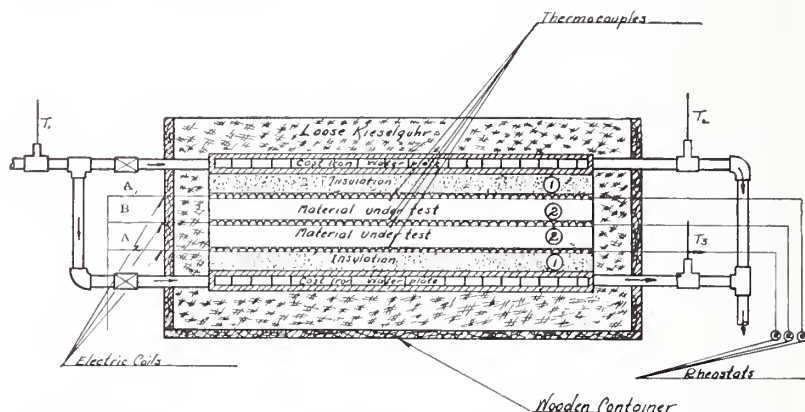


FIG. 3.—Apparatus for determining heat transmission keeping a constant difference in temperature.

1. Insulation to help maintain and regulate temperature of outer surface of material.

2. Material under test.

3. Cast iron water plate for cooling and regulating temperatures of outer surface of material under test.

Coils A_1 , A_2 and B are made alike, and are duplicates of the heating coil shown in figure 1.

The electric connection on coils B , A , A_2 , are shown in figures 4 and 5, respectively.

The method of calculating the transmission is the same as explained in the fore part of this paper, except that the tempera-

ture drop through layer 2 is measured instead of the total drop to the water plate.

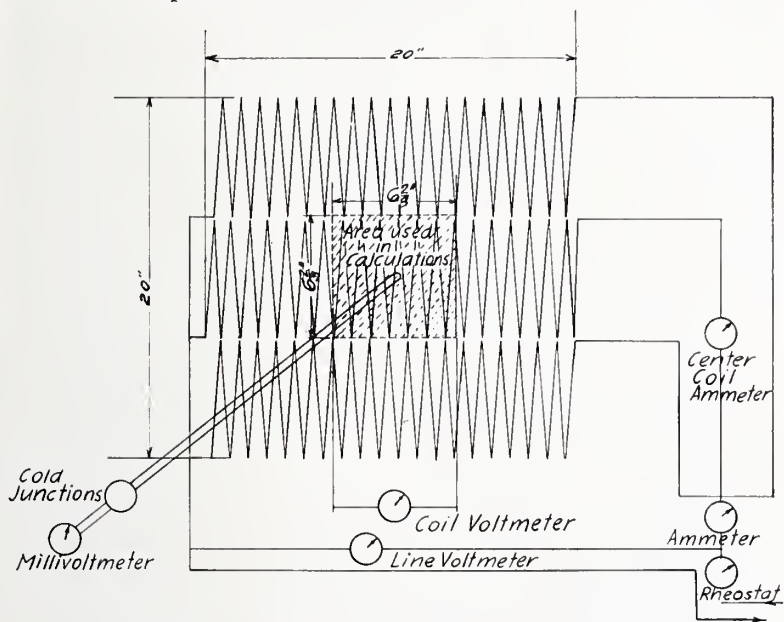


Fig. 4.—Diagram showing electrical connections. Coil B.

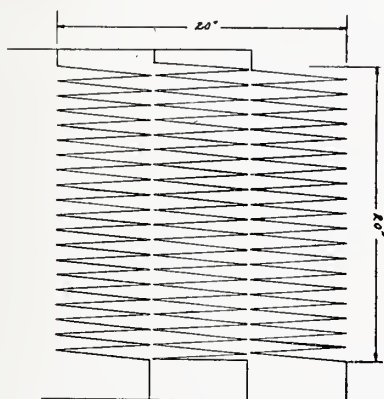


FIG. 5.—Diagram showing electrical connections. Coils A and A₂.

The heat generated in coil *B* must pass through the layer of material (2), if the temperature of coils *A1* and *A2* are less than that of coil *B*.

Care must be taken to allow plenty of time for the apparatus to establish equilibrium. It can readily be seen that there is a possibility that the temperature in the center of the material under test would be less than either surface until equilibrium is established. This apparatus comes to equilibrium in 36 hours if material under test is less than $2\frac{1}{2}$ inches. More time is necessary if the material is thicker.

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Discussion

DR. E. W. WASHBURN: The author has asked me to discuss his paper, especially in regard to its possibilities as to accuracy. The modifications which Mr. Horning has made in the hot-plate method are in the right direction, and they result in the elimination of important sources of error in this method. By still further refinements in the apparatus, it seems to the writer that the method could be made still more accurate if desired. The modifications which suggest themselves are the following:

(1) For heating the inner surface of the material under test, electrically heated metallic plates, rather than simply heating coils should be employed, to insure the uniform temperature distribution over the surface.

(2) The plate covering the area used in the calculation should be independent of the other heating plates, so that its temperature could be varied up and down at will.

(3) By applying the author's principle also to the cooled surface, an independent check upon the results could be secured. This would require the separation of the portion of the cold plate immediately opposite the heated area used in the calculation, from the remainder of the cold plate, so that the cooling water used for this portion of the area could be weighed.

(4) If desired, an extra refinement could also be introduced in the direction of better contact between the two plates and the surface of the material under test. Thus, for example, the smooth contact surfaces of the plates might be tinned or gold plated and

pads of leaf or of thin foil (tin or gold) might be employed between the plates and the surfaces of the material under test. By applying pressure to the plates, these pads would be forced into the crevices of the surface, thus insuring better contact.

MR. C. F. GEIGER: Details of methods, especially of the "continuous transmission determinations," are not sufficiently explicit. For the data given in figures 2 and 3, it is not stated what the cold-side temperature was. Presumably it was constant for all the tests and was about 70°F .

An elaboration of this method, if a suitable means of obtaining a uniform heating can be devised, for determining the heat transmission power of refractories at temperatures ranging from 1000 to 1500°C , or higher, and with temperature differences of from 100 to 300°C would be of great value.

We have indeed reached a time in the development and requirements of refractories that necessitates our knowing the properties of such material at the temperatures of use. It should no longer be permissible to assume that a heat transmission factor determined at 100°C applies at 1300°C .

It appears that inasmuch as heat transmission will comprise emissivity and surface resistance as well as true conductivity, we are likely to get widely differing results, depending upon the method of heat transfer from the heating surface. At extremely high temperatures it is likely that radiation is a more potent factor in heat transfer than either convection or conduction. In other words, a given refractory will, in a small measure, do the work it is made to do. In work similar to that described, it was demonstrated that increasing the rate of flow of water through the cooling plate increased the heat transmission or apparent thermal conductivity of the material under test.

The method, however, seems to be very satisfactory and requires only standardization of such details.

MR. S. F. WALTON: In this very interesting paper, Mr. Horning appears to have developed an excellent method of determining heat transmission applicable to certain types of conductivity problems. By his method the material under test is in physical contact with a solid heating unit and its outer surface

is kept at a definite lower temperature. The data obtained should be very valuable in problems of insulating such installations as steam pipes, boilers, low temperature ovens where the heat is carried to the walls largely by gaseous conduction, and for furnace walls not including the portion next the heated chamber. It is very doubtful, however, if data obtained by this method can be applied to the calculation of flow of heat through muffle walls, saggars, combustion chambers, recuperators, etc., especially at high temperatures, where heat is being transmitted from one gas filled chamber to another largely by radiation. Data on such heat transmission are very scanty and must be obtained by some method which much more closely parallels actual conditions in these cases than does the hot plate method.

AUTHOR'S CLOSURE: Dr. Washburn has made some excellent points in regard to refinements of this method. The author tried at one time to adopt the principles set forth in Dr. Washburn's second and third remarks. Difficulty arose in trying to get the temperature of the center coil exactly the same as the rest of the area. In trying to use a heat balance made on the water plate directly over the area of calculations, it must be remembered that in order to make a heat balance it is necessary to account for all the heat put in. If the water adjacent to the water in the center one-ninth is hotter or colder than the temperature of the water in the center one-ninth, heat will be either absorbed or lost, thus destroying the accuracy of the balance. An attempt is now being made to overcome this error, but so far no success has been encountered.

Mr. Geiger makes the statement that heat transmission will be comprised of emissivity and surface resistance as well as true conductivity. This no doubt is true.

The writer contends that if the temperature difference is measured within the material and not directly between the actual surfaces, that these temperatures are a resultant of the effects of emissivity, etc. The transmission figures calculated on this basis, will be a resultant transmission, depending on the emissivity of the material.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

THE POPPING (UN SOUNDNESS) OF LIME PLASTER^{1,2}

BY WARREN E. EMLEY AND CECIL H. BACON

Introduction

In the "good" old days, specifications for lime plaster required that the lime be soaked with an excess of water for a year or so before it could be used. Of course, any attempt to enforce such a specification to-day would be ridiculous: it would simply rule lime off the market.

During the transition period from the past to the present method of making lime plaster, lime was sometimes put on the wall before it had been properly slaked. The result was a kind of expansion peculiar to the material. The expansion was confined to certain nuclei dotted throughout the plaster. These little particles frequently expanded so much as to push themselves clear out of the wall and fall off, leaving small holes in the plaster. This phenomenon became known technically as "popping." Its seriousness depended upon the size and number of the holes. Sometimes it required very close inspection to see the holes, in other cases the popping was so noticeable as to require refinishing the wall.

The lime manufacturers soon found that it did not pay to market a lime which would pop. The result was a gradual improvement in the process of manufacture, until now damage claims for popping are extremely rare.

However, popping is not by any means a dead issue. In the first place, the popping has not been entirely stopped. It has simply been controlled to such an extent that the holes now caused by it are so small as to pass any but the most minute inspection. Serious popping still occurs, although very rarely. There has long been a suspicion that these cases are not due to the lime, and the lime manufacturers desire to be shown why they should settle the damage claims arising therefrom. The

¹ Received August 1, 1920.

² Published by permission of the Director, Bureau of Standards.

improvements made in the process of manufacture of lime have been made blindly. The popping has been practically stopped, but no one seems to know just how it was done. Therefore, with any introduction of new methods into the manufacturing process, there is always the danger that the old trouble may recur. A great deal of hydrated lime is now being used as an admixture with cement mortars and concretes. Unsoundness has long been considered a dangerous property of portland cement. Popping is a phenomenon somewhat similar to unsoundness, and it was therefore believed that a lime which will pop is not fit to be used with cement.

The above reasons all pointed to the fact that a requirement for soundness, or freedom from popping, should be included in any specifications for lime. Accordingly, Committee C-7 of the American Society for Testing Materials, whose function it is to prepare such specifications, attempted to develop a method of testing for the popping of lime.

There were two methods of testing for soundness then available: the standard method for portland cement,¹ and the Le Chatelier method for hydraulic limes and cements.² Both of these methods subject the set material to the action of live steam and note the expansion caused thereby. The first attempt was to modify the cement method, making the test specimens of 50 per cent of cement known to be sound and 50 per cent of the lime being examined.³ It was finally decided that both of these methods are fundamentally wrong: that popping is quite different in its nature from unsoundness. Popping is caused by the expansion of a few particles distributed throughout the mass. Lime plaster as a whole usually contracts as it sets, and this contraction will not be noticeably lessened by the expansion of a few particles in the plaster, unless the number and size of these particles be excessive. Any measurement of the movement of the plaster as a whole can therefore not be relied upon as an indication of its content of particles which might cause popping.

¹ Bureau of Standards, *Circular* 33.

² British and French standard method, Taylor, "Practical Cement Testing," 1905.

³ A. S. T. M. Standard Specifications for Hydrated Lime, C-6-15.

This criticism was met by adopting an entirely different method of test. The test specimen is made of two coats of plaster. The first coat consists of one part of the lime being examined and four parts of sand. After this has set, it is covered with a skim coat of three parts of the lime to one part of calcined gypsum. When the skim coat has set, the specimen is exposed to live steam, and the presence or absence of pops is noted.¹ This method seems to have given entire satisfaction. However, the word "seems" is used advisedly, because it is not definitely known that a lime which pops when tested by this method will actually pop on the wall.

Committee C-7 felt that they could not answer this question without having a complete knowledge of the fundamental causes of popping. This information they requested the Bureau of Standards to develop. In compliance with this request, an extensive investigation of the subject has been completed, and this paper embodies some important conclusions derived therefrom.

Experimental

The test specimens were made of two coats of plaster, in the manner just described, but instead of being exposed to live steam, they were exposed merely to the action of the air in the room, in a manner similar to the storage conditions of plaster in actual use. These specimens have been examined at frequent intervals during fifteen months.

The original series, comprising 72 specimens, was designed to determine the effect of such factors as underburned or overburned lime, the method of slaking the lime, the quality of the sand, and the addition of certain suspicious impurities.

Without going into details about the composition and examination of these specimens, it may be stated briefly that this series brought to light two facts which required further investigation: The chlorides of sodium and magnesium (common constituents of salt water), while they do not cause popping, do cause serious discoloration of the plaster. A second series of specimens was

¹ A. S. T. M. Tentative Specifications for Masons' Hydrated Lime, C-6-19-T.

made to determine the maximum permissible limit of these materials. Eight of the twelve building sands used in the first series caused popping. A complete petrographic analysis of each of these sands was made, but failed to throw any light on the subject, for reasons to be explained later.

The next series of experiments started from an entirely different angle: It was accidentally discovered that a rather impure hydrate, when soaked over night with water in the customary manner, developed the usual buff color. But when it was soaked in an air-tight container, the color was green instead of buff. This led to a suspicion of ferrous iron, which was easily confirmed by qualitative tests. In a paper read before the Inter-departmental Conference on Chemical Lime, Mr. G. F. Loughlin, of the U. S. Geological Survey, stated that ferrous carbonate is a very common constituent of limestone. It is also quite probable that ferrous salts could be introduced from the ash of the fuel, if the atmosphere in the kiln is reducing.

In order to confirm this point, a third series of specimens were made, containing iron in the metallic, ferrous, and ferric condition. It was found that both the metallic and the ferrous iron quickly changed to the ferric condition, with consequent expansion and popping.

When lime is burned in a pot kiln, the fuel is fed in alternate layers with the stone. The ash of the fuel is therefore in immediate physical contact with the lime. In a flame kiln, the coal is burned in external fire boxes, and only the gases of combustion pass into the kiln. However, the fires must be cleaned once a day, and it usually happens that during this operation some of the accumulated ash on the grates is pushed over the bridge wall and into the kiln. When the fuel used is producer gas, the lime should be quite free from ash, but unfortunately the gas mains must be cleaned at least once a week. It is customary to blow the soot and ash which have accumulated in the mains directly into the kiln.

Coal ash is distinctly acid in its chemical nature; lime is strongly alkaline. The temperature in a lime kiln is such as to insure a chemical combination between the ash and the lime. The evidence of such combination is very plain: hard, vitrified crusts

of material of a brown or black color are found on the surface of the lumps of lime.

Of course, there are ingredients other than iron in coal-ash which might cause trouble. Certain compounds of lime and silica, or of lime and alumina, will hydrate slowly when exposed to water, and will expand as they hydrate.¹ This is particularly true of those compounds in which the base (lime) is in chemical excess of the acid (silica or alumina), and which would therefore be expected to be formed under the conditions prevalent in a lime kiln. It is impossible to identify these compounds by means of analytical chemistry. Owing to the fact that they usually occur in an extremely finely divided or colloidal state, their identification by means of the microscope is almost equally difficult. This difficulty of the identification of the compounds of lime, magnesia, silica, alumina, and iron, probably accounts for the failure of the petrographic analyses of the sands used in the first series to show why certain sands caused popping.

The fourth line of attack was to pick the centers out of some pops which had occurred in a wall, thereby collecting enough material for chemical and microscopic examination. The chemical composition of this material was found to be as follows:

| INSOLUBLE IN 10% HYDROCHLORIC ACID. | |
|-------------------------------------|--------|
| | %. |
| Silica..... | 26.32 |
| Oxides of iron and aluminum..... | 2.27 |
| SOLUBLE IN 10% HYDROCHLORIC ACID. | |
| Silica..... | 8.17 |
| Alumina..... | 4.86 |
| Ferric oxide..... | .78 |
| Ferrous oxide..... | .31 |
| Calcium oxide..... | 34.50 |
| Magnesia..... | 5.10 |
| Sulphuric anhydride..... | 1.97 |
| Loss on ignition..... | 15.01 |
| | <hr/> |
| | 100.07 |

On the assumption that all of the insoluble matter is sand or clay, that all of the "loss on ignition" is carbon dioxide, and that

¹ Klein and Phillips, "Hydration of Portland Cement," Bureau of Standards, *Technologic Paper* 43.

all of the magnesia is present as carbonate, the above analysis may be recalculated as follows:

| | |
|-----------------------------|--------|
| Sand and clay..... | 29.37 |
| Magnesium carbonate..... | 10.71 |
| Calcium carbonate..... | 21.37 |
| Calcium sulphate..... | 3.35 |
| Calcium ferrite..... | .55 |
| Calcium ferrate..... | 1.05 |
| Mono-calcium aluminate..... | 7.53 |
| Mono-calcium silicate..... | 19.62 |
| Di-calcium silicate..... | 6.52 |
| | <hr/> |
| | 100.07 |

The above assumptions are undoubtedly fallacious, but the composition calculated thereon proves conclusively that the material is basic rather than acidic in its nature: that the lime and magnesia are more than equivalent chemically to all of the acid radicals. It was possible, by means of the microscope, to identify magnetite and calcium disilicate in the material. This means that some of the compounds present must be still more basic than those included in the above list. It will be remembered that the highly basic silicates and aluminates of calcium are the ones which may be expected to cause popping.

Another phase of this investigation had to do with certain mechanical features. It is obvious that an unsound particle in the finish coat of plaster will be able to give evidence of its presence by popping, without let or hindrance. But suppose the particle is in the brown coat, will it have sufficient expansive force to push its way out through a sound finish coat? The expansive force of an unsound particle, and also the size of the hole left by it after popping, will depend upon the size of the particle. There must therefore be a certain limiting size, below which either the particle will not undergo sufficient expansion to pop, or else the hole which it leaves on popping is so small that it does not affect the satisfactory appearance of the plaster. It was found that ferrous sulphate could be depended upon to cause popping, so another series of specimens was made, in which this material was used in different positions in the plaster, and in different sized particles.

Conclusions

It will be noted that all of these tests produce results which can be stated only as matters of personal observation, and not of exact measurement. The attitude of the observer therefore has some influence in deciding whether or not a certain specimen has popped. Holes which are not noticeable on casual inspection are quite prominent when the plaster is examined with the aid of a hand lens. In spite of this personal factor, it has been found possible to draw certain conclusions with a reasonable assurance of their being correct. These are as follows:

1. The popping of a lime plaster is caused by the presence of grains of a material which hydrates slowly and expands as it hydrates.

2. This material may be a compound of calcium with silica, alumina, or iron, or it may be an incompletely oxidized salt of iron.

3. Such compounds may be introduced as impurities in the limestone, as ash from the fuel, or as impurities in the sand.

4. When such impurities are uniformly distributed throughout the limestone, they will not cause trouble, even when the lime is overburned, if two precautions are observed: the hydrate should be screened through a No. 48 sieve, and should be soaked over night before using.

5. When the impurities occur along bedding planes on the stone, or as balls of clay adhering to the stone, or are introduced as ash from the fuel, they can be identified by the formation of a dark vitreous crust on the surface of the lime. All such lime should be discarded as unfit for plastering.

6. The sand should contain not more than one per cent of the chlorides of sodium and magnesium. Common clay, leaf mold, and similar impurities, do not cause popping. Ferrous carbonate and magnetite are apt to cause trouble if they occur in particles coarser than 48 mesh.

7. Referring only to these impurities which commonly occur in lime, it may be stated that those particles which are large enough to stay on a No. 30 screen will be almost certain to cause noticeable popping. Those which pass a No. 30 and are retained

on a No. 48 screen may or may not be troublesome. Those which pass a No. 48 screen will not cause noticeable popping, if the lime is soaked over night before use.

8. Production of lime which will not pop may be assured by following these three precautions: (a) Reject all lumps of lime which are encrusted with vitreous material. (b) Screen all hydrate through a No. 48 sieve. (c) Soak all lime putty over night before using it as a plaster.

9. Popping can be caused by impurities in the brown coat as well as in the finish coat. The above precautions should therefore be applied to both masons' hydrate and finishing hydrate.

10. The method of testing for popping now in use is fundamentally sound and gives satisfactory results. It is believed, however, that a requirement for fineness would be of greater value as a part of standard specifications for lime.

Acknowledgment is hereby made to Mr. William B. Orange for some of the experimental work, to Mr. H. A. Bright for the chemical analyses, and to Mr. A. B. Peck for the microscopic examinations involved.

BUREAU OF STANDARDS
WASHINGTON, D. C.

THE EFFECT OF WET GRINDING, SCREENING AND ELECTROLYTES AND DEXTRINE ON CLAYS OF LOW PLASTICITY AND STRENGTH^{1,2}

BY H. W. DOUDA

Many clays which otherwise possess good properties lack in plasticity and strength and therefore their use is limited. Plastic refractory clays are comparatively scarce in certain isolated cases in localities where non-plastic refractory clays are abundant. It was the purpose of this investigation to determine to what extent the plasticity and strength of non-plastic fire clays can be increased by special treatments such as wet grinding, the addition of electrolytes, removing the coarse material by screening and by the addition of an organic binder like dextrine.

Description of Work

Three clays were selected for this work, namely: (1) an Ohio plastic stoneware clay; (2) a Maryland flint clay and (3) an Ohio semi-flint clay. These were crushed to 20 mesh size and mixed thoroughly by shoveling. The total batches were then divided into portions of 15 pounds each and treated as follows.

The 15 pound portions were ground wet in a small laboratory wet pan for 30, 60 and 120 minutes. The dimensions of the pan are as follows: Outside diameter of pan, $22\frac{1}{4}$ inches; diameter of mullers, $9\frac{3}{4}$ inches; thickness of mullers, $2\frac{3}{16}$ inches. The pan operated at 60 revolutions per minute. In order to get more comparable results, distilled water was used in all cases to eliminate the effects of soluble salts which are present in the city water.

One series of tests was made by wet grinding the clays without the addition of electrolytes; a second series was treated by wet grinding with 1 per cent NaOH; a third series was treated with

¹ By permission of the Director, U. S. Bureau of Mines.

² Read Feb. 23, at the meeting in Philadelphia.

1 per cent NaOH and the coarse material was removed by screening; and a fourth series was treated by wet grinding with 1 per cent NaOH and 1 per cent dextrine and screening through a 150-mesh sieve to remove the coarse material.

Cross-breaking strengths were determined in the dry condition and after firing to cone 2. The water of plasticity, drying shrinkage, dry density, firing shrinkage and porosity of the fired specimens were determined in the customary manner.

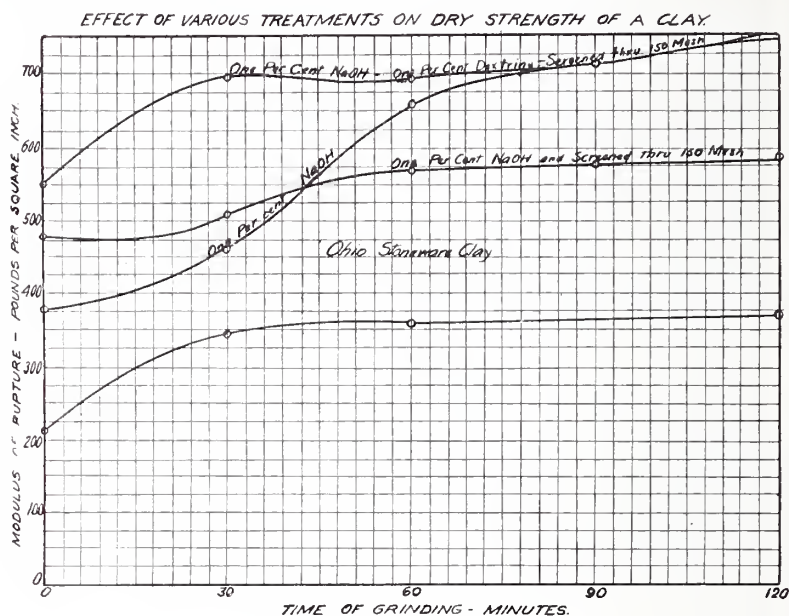


FIG. 1.

Elutriation tests¹ were also made in order to compare the effects of these treatments on the fineness of grain of the products.

Results of Work

Strength.—The results of these treatments are shown in table 1 and figures 1, 2, 3 and 4. With the stoneware clay the dry strength

¹ The elutriation tests were made according to the method given by H. G. Schurecht, "Elutriation Tests on Some American Kaolins," *J. Am. Ceram. Soc.*, p. 355, 3, No. 5, May 1920.

EFFECT OF VARIOUS TREATMENTS ON DRY STRENGTH OF A CLAY.

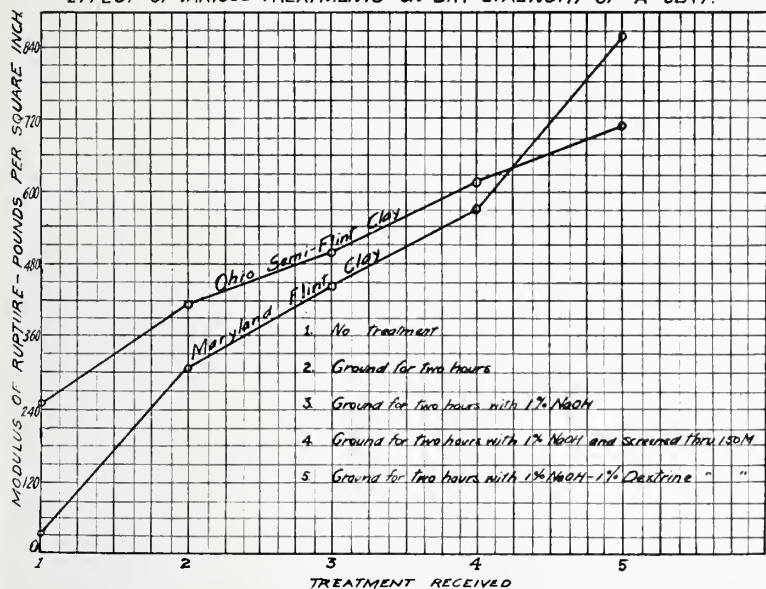


FIG. 2.

THE EFFECT OF VARIOUS TREATMENTS ON THE BURNED STRENGTH OF A CLAY BURNED TO CONE 2.

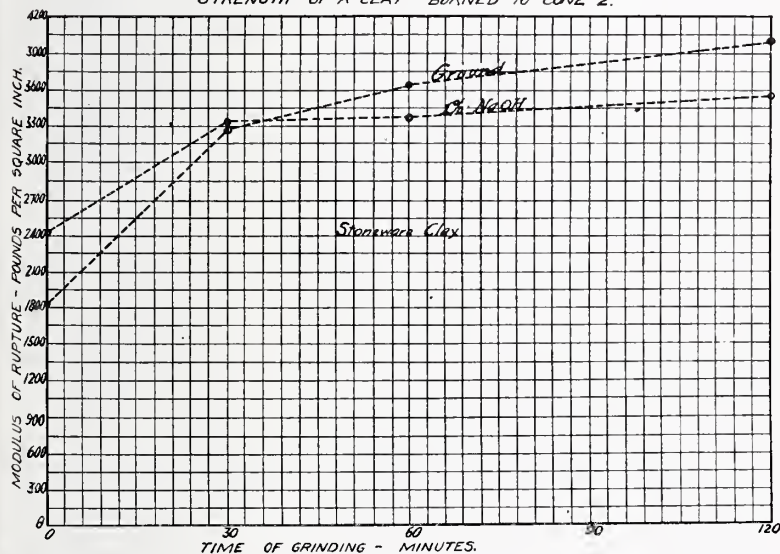


FIG. 3.

was increased 74.38 per cent. The same clay with no grinding, but with an addition of one per cent of caustic soda, increased the strength 79.22 per cent. By a combination of wet grinding and the addition of caustic soda, an increase of 255.76 per cent was obtained.

The greatest percentage increase was noted with the flint clay, which in the untreated condition has a modulus of rupture of only 35.31 pounds per square inch. By grinding two hours this

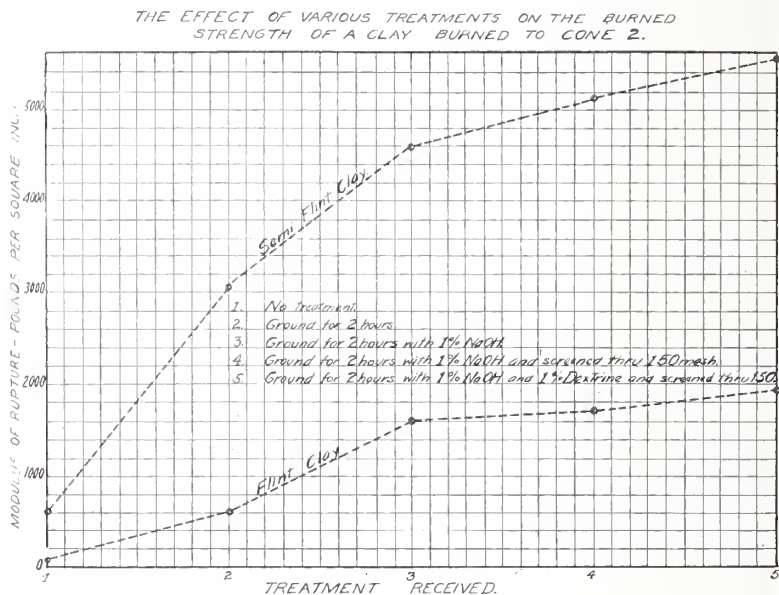


FIG. 4.

was increased to 305.38 pounds per square inch. On the addition of one per cent caustic soda an additional increase to 439.46 pounds per square inch was obtained.

Screening the clays through a 150-mesh sieve and adding one per cent dextrine gave additional strength to all the clays thus tested.

Some of the test bars containing caustic soda showed scumming after drying. This was most noticeable in batches which were not ground in the wet pan while those which were ground for

TABLE I.—THE EFFECT OF TREATMENTS ON THE RAW AND FIRED STRENGTH OF CLAYS
Modulus of Rupture—Lbs. per Square Inch

| Clay Tested | Time of grinding in minutes | 1 Clay Alone | | 2 Treated with 1% NaOH | | 3 Treated as in No. 2 and screened thru 150 mesh sieve | | 4 Treated with 1% NaOH 1% dextrine and screened through 150 mesh sieve | |
|-----------------|-----------------------------|-----------------|-----------------|---------------------------|-----------------|---|-----------------|---|-----------------|
| | | Dried at 110°C | Fired at cone 2 | Dried at 110°C | Fired at cone 2 | Dried at 110°C | Fired at cone 2 | Dried at 110°C | Fired at cone 2 |
| Stoneware..... | 0 | 211.61 | 1823.80 | 379.25 | 2405.7 | 847.85 | .. | 973.50 | .. |
| Stoneware..... | 30 | 346.68 | 3274.90 | 458.31 | 3318.8 | 895.89 | .. | 1221.20 | .. |
| Stoneware..... | 60 | 364.36 | 3630.30 | 659.72 | 3346.2 | 1006.94 | .. | 1220.00 | .. |
| Stoneware..... | 120 | 368.81 | 4080.70 | 752.83 | 3554.4 | 1034.39 | .. | 1345.00 | .. |
| Flint..... | 0 | 35.31 | 65.20 | .. | ... | ... | .. | ... | .. |
| Flint..... | 120 | 305.33 | 601.96 | 439.46 | 1606.08 | 569.66 | 1702.8 | 861.42 | 1913.4 |
| Semi-flint..... | 0 | 251.71 | 602.20 | .. | ... | ... | .. | ... | .. |
| Semi-flint..... | 120 | 416.20 | 3045.20 | 499.46 | 4591.5 | 620.52 | 5171.1 | 713.61 | 5593.3 |

TABLE 2.—THE EFFECT OF TREATMENTS ON THE PROPERTIES OF CLAY

| Clays Tested | Time of grind- ing in minutes | Clay alone | | | | Surface factor | | | | |
|-----------------|-------------------------------------|--------------------------------------|----------------|---|--------------------------------------|--------------------------------|---|--|---|---|
| | | Drying shrink- age per cent | Dry density | Water of plasti- city per cent | Firing shrink- age per cent | Porosity fired at cone 8 | 1 No treat- ment Surface factor | 2 Treated with 1% NaOH Surface factor | 3 Treated as in 2 and screened thru 150 mesh Surface factor | 4 Treated as in 3 with 1% dex- trine added Surface factor |
| | | | | | | | | | | |
| Stoneware..... | 0 | 13.55 | 1.98 | 18.50 | 18.47 | 0.351 | 7,352.40 | 5,705.66 | ..... | ..... |
| Stoneware..... | 30 | 14.07 | 1.86 | 22.86 | 18.45 | .245 | ..... | 12,061.75 | ..... | ..... |
| Stoneware..... | 60 | 15.93 | 1.84 | 22.87 | 18.52 | .800 | 9,122.26 | 13,102.32 | ..... | ..... |
| Stoneware..... | 120 | 15.79 | 1.85 | 23.40 | 18.50 | .610 | 9,385.96 | 13,384.60 | ..... | ..... |
| Flint clay..... | 0 | ... | .. | ... | ... | ... | 2,398.45 | ..... | ..... | ..... |
| Flint clay..... | 120 | ... | .. | ... | ... | ... | 7,464.62 | 9,752.36 | 9,469.80 | 13,334.60 |
| Semi-flint..... | 0 | ... | .. | ... | ... | ... | 5,643.36 | ..... | ..... | ..... |
| Semi-flint..... | 120 | ... | .. | ... | ... | ... | 9,951.20 | 10,604.93 | 13,930.06 | 14,003.98 |

two hours showed considerably less scumming. The addition of dextrine overcame the scumming in nearly all cases.

The fired specimens showed a similar increase in strength due to wet grinding and the addition of caustic soda, but only a small increase where dextrine was used, due to the burning out of the dextrine.

Plasticity.—The plasticity was increased in each of the clays by wet grinding, screening and the addition of one per cent of dextrine. The decrease in moldability due to the addition of one per cent caustic soda was not so noticeable in this case as it was where 50 per cent of flint was used with the clay. In fact, judging by feel, the plasticity of those clays treated with soda seemed to be greater than those not treated, although they were tougher and harder to mold.

Wet grinding increased the drying shrinkage, decreased the dry apparent density, and increased the water of plasticity whereas the firing shrinkage and porosity remained practically the same when fired to conc 2.

Elutriation Tests! The results of the elutriation tests are shown in table 2. The increase in fineness of grain is shown by the increase in surface factors of the clays after wet grinding for various periods. The addition of caustic soda to the clay in grinding caused an additional increase in fineness, evidently due to the dispersion of the clay aggregates.

With stoneware clay, wet grinding for two hours increased the surface factor 27.6 per cent, whereas wet grinding for two hours with one per cent caustic soda increased the surface factor 81.9 per cent, showing that with this clay the caustic soda was more effective than wet grinding in increasing the fineness of grain. The flint and semi-flint clays, on the other hand, were more affected by wet grinding than by addition of electrolyte. Obviously the fineness of a flint clay will respond to wet grinding, whereas its clay aggregates are made up of particles more or less cemented together, hence do not respond readily to the dispersive effect of the electrolyte, even though the dry strength is very materially increased.

Summary

The results of the foregoing work indicate that the dry strength of clays can be increased 76.2 to 675.0 per cent by wet grinding for two hours.

An additional increase of 19.1 to 78.3 per cent was obtained by adding one per cent of caustic soda to the clay and wet grinding.

By removing the coarse material by screening the clay through a 150-mesh sieve an additional increase in strength of 24.0 to 35.5 per cent was obtained.

The addition of one per cent dextrine caused an additional increase of 16.1 to 52.6 per cent, depending on the character of the clay.

A combination of the above treatments caused an increase in dry strength of 188 to 2050 per cent.

Plasticity of the clays was increased by wet grinding, screening and the addition of one per cent dextrine.

The addition of one per cent caustic soda caused the clay to become tougher in the plastic condition and somewhat more difficult to mold, though not seriously so.

Scumming was noticed in some cases where soda had been used and where wet no grinding had been given the clay.

This may be overcome by the use of dextrine with the soda, or the use of a smaller amount of soda, 0.5 to 0.7 per cent.

The drying shrinkage was increased, the apparent density decreased and the water of plasticity increased by wet grinding.

The fineness of grain of the clay was increased by wet grinding and also an additional increase was obtained by adding one per cent caustic soda.

The strength of the clays after burning was increased 127 to 1700 per cent by the above treatments.

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NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

UNITED STATES PATENTS RELATING TO ENAMELS WITH SPECIAL REFERENCE TO ENAMELS FOR IRON AND STEEL¹

BY CLARENCE JAY WEST

The following pages contain a list of the United States patents relative to enamels, with special reference to those for iron and steel for the period 1900-1920. These are arranged chronologically. Wherever possible reference is given to Chemical Abstracts, where a more complete abstract of the patent may usually be found. Reference is also made (the figures in parentheses), to the Official Gazette of the U. S. Patent Office, where the more important, if not all, the claims of the patents are printed. Printed copies of patents are furnished at 10 cents each by the Commissioner of Patents, Washington, D. C.

640,844. Charles H. Watermann. Process of enameling. Jan. 9, 1900. (90, 279).

645,393. Edward C. Hoelscher and John Clifford. Enameling table or machine. Mar. 13, 1900. (90, 2076).

645,517. Christian A. Sievert. Enameling table. Mar. 13, 1900. (90, 2121).

658,833. Edward Dithridge. Enameling table for bath tubs. Oct. 2, 1900. (93, 45).

663,601. William C. Degelman. Apparatus for enameling bath tubs. Dec. 11, 1900. (93, 1911).

663,618. Wilbur Topping. Composition for enameling metal ware. Dec. 11, 1900. (93, 1996).

The formula used was: 61 parts borax, 71 parts feldspar, 44 parts quartz, 15 parts fluorspar, 14 parts soda, 11 parts saltpeter and water.

664,321. Josiah Hughes and James F. McGowan. Ornamental enamel ware. Dec. 18, 1900. (93, 2285).

Variegated enamel ware, the surface of which comprises a body having incorporated and fused therein an enameling material of different color.

669,567. Charles H. Watermann. Apparatus for enameling surfaces of refractory material. Mar. 12, 1901. (94, 1999).

674,506. Joseph H. Hines. Process of enameling metal surfaces. May 21, 1901. (95, 1509).

¹ Received Aug. 1, 1920.

679,300. William A. Dunpal. Enameling metal. July 30, 1901. (96, 854).

A thin finish coat is applied to a burned ground coat and while this is still wet, a second thin coat of a contrasting color is applied.

684,979. Edward Dithridge. Manufacture of enamels (apparatus). Oct. 22, 1901. (97, 638).

691,268. William Jankowsky. Enameling metal ware. Jan. 14, 1902. (98, 365).

Iron or steel is coated with a suitable primary coating (alkali carbonate) and an enamel coat containing a suitable percentage of primary or acid salt capable of decomposing the film.

700,021. Edward Dithridge. Enameling fork for bath tubs. May 13, 1902. (99, 1542).

707,490. Carl H. Zwerman. Enamel sifting apparatus. Aug. 19, 1902. (100, 1732).

708,363. George W. Ketcham. Art of enameling metal ware. Sept. 2, 1902. (100, 2115).

The cleaned article is coated with a thin layer of cohesive and non-corrosive metal and an enamel then applied which, upon heating, will coact with and only partially oxidize and permeate the coating metal.

709,530. Daniel Wieser. Manufacturer of enameled metal plates. Sept. 23, 1902. (100, 2460).

The plates are coated with a mixture of zinc white and oil varnish, dried, then coated with a greasy lacquer color, dried and rubbed.

710,443. Paul Dupont. Machine for mechanically enameling baths or other metal objects. Oct. 7, 1902. (101, 19).

716,106. Rudolf Rickmann. Manufacture of white or light-colored enamels. Dec. 16, 1902. (101, 2460).

Sodium antimoniate is fused with the enamel.

721,155. Hubert Claus. Enamel machine. Feb. 24, 1905. (102, 1565).

733,831. Samuel H. Frisk. Work holder for enameling. July 14, 1903. (105, 446).

758,325. Thomas M. Sunan. Manufacture of enameled ware. Apr. 26, 1904. (109, 2307).

The cleaned article is coated with an enamel carrying metallic bodies, a non-metallic hydroxide added and heated to flux and set the enamel.

759,351. Edward L. Dawes. Enameling device. May 10, 1904. (110, 380).

762,547. Henry C. Milligan. Process of enameling steel ware. June 14, 1904. (110, 1860).

Steel is pickled, washed, dried, immersed in an acid solution and coated while wet with alkaline liquid enamel, dried and fused.

771,507. Thomas L. Strong. Apparatus for drying enameled ware. Oct. 4, 1904. (112, 1080).

774,478. John S. Jobe. Enameling kiln. Nov. 8, 1904. (113, 420).

774,491. Charles F. Pfalzgraf. Enameling metal. Nov. 8, 1904. (113, 425).

779,655. Julius F. Kenkel. Manufacture of enamel ware. Jan. 10, 1905. (114, 388).

The plate is coated with a preparation of enamel, burned, the plate then slushed in an enamel preparation and the enamel evenly distributed by a blast of air.

793,659. Otto L. Heintz. Enameled ornament. July 4, 1905. (117, 14).

804,010. Julius F. Kenkel. Enameling. Nov. 7, 1905. (119, 203).

An iron or steel article which has a fundamental coat composed of clay and an oxidizing agent and a separately applied glaze coat covering the fundamental coat and forming therewith a mottled finish.

806,153. Walter J. Kohler. Process of making speckled enameled ware and the product thereof. Dec. 5, 1905. (119, 1293).

The process consists of mixing a comparatively small amount of comminuted carborundum with dry pulverized enameling material of one color (different from the carborundum), putting the mixture on the article to be coated with enamel, and then subjecting the article to such heat as fuses the enameling material but less than sufficient to fuse the carborundum.

808,542. Joseph H. Hines. Process of enameling. Dec. 26, 1905. *J. Soc. Chem. Ind.* 25, 1220 (119, 2458).

After cleaning the metal is coated with an alkaline material, the enamel is then applied, a coloring coat applied and burned, and a second coat of enamel applied and burned.

808,744. Otto L. Heintz. Enameled ornament. Jan. 2, 1906. (120, 57).

826,628. Samuel H. Thurston. Process of enameling metal and the resulting product. July 24, 1906. (123, 1061).

The process consists in first forcibly beating one metal into and upon the other systematically and continuously until the particles or molecules of the coating metal are driven into the metal being coated and incorporated with the particles at and beneath the surface of the same.

843,985. Wm. Atkinson and Joseph Smith. Enameling metals. Feb. 12, 1907. *C. A.*, 1, 919. (126, 2390).

Also English patent 12,554. May 30, 1906. *C. A.*, 1, 938.

A flux of white opal cullett 130, sodium bicarbonate 20, and boric acid 12 parts is ground in water to a fine powder, applied to the article and burned.

862,285. Charles R. Schmidt. Method of enameling. Aug. 6, 1907. *J. Soc. Chem. Ind.* 26, 1009, (129, 2175).

The article to be enameled is heated in a rotating enameling chamber or furnace containing dry enamel material.

866,821. Arthur R. Speer. Method of enameling the interior of sheet metal vessels. Sept. 24, 1907. (130, 1092).

868,078. William A. Dunlap. Enameled ware. Oct. 15, 1907. (130, 1772).

869,155. Grace M. Banning. Metal enameling. Oct. 22, 1907. (130, 2321).

906,628. Everett D. Holley. Enamel ware. Dec. 15, 1908. (137, 1528).

932,839. Rudolph Weimer. Substitute for tin oxide for enameling metal ware. Aug. 31, 1909. *C. A.*, 3, 2554. (145, 1165).

The boiled, roasted and ground product of Sb oxide 70, NaOH 28, NaNO₃ 22, kaolin 10 and barytes 10.

971,641. George L. Rice and Benjamin W. Gilchrist. Enameling metallic articles. Oct. 4, 1909. *C. A.*, 5, 31. (159, 49).

A coating containing a magnetic material and sulfur is deposited upon the article electrolytically and the enamel is applied to this.

994,162. Edgar L. Hull. Producing flat watch dials, enameled on one side. June 6, 1910. *C. A.*, 5, 2540. (167, 22).

Both sides are enameled and the enamel then removed from one side by the action of HF.

995,724. C. Rosenzweig. White enamel for glazed goods. June 20, 1910. *C. A.*, 5, 2711. (167, 625).

A glazing mass and a silicate of Zr, Th, Gl, La, or Yt.

996,226. Charles W. Ebeling. Enameling table. June 27, 1911. (167, 832).

1,001,511. J. H. Danver. Making mottled or colored enamels. Aug. 22, 1911. *C. A.*, 5, 3898. (169, 890).

1,017,360. D. A. York and J. A. Tinker. Enameling steel, etc. Feb. 13, 1912. *C. A.*, 6, 920. (175, 424).

1,024,405. K. Kreidl. Making a filler for white enamel. Apr. 23, 1912. *C. A.*, 6, 1666. (177, 987).

Zirconium silicate and sodium hydroxide.

1,033,821. George R. Meyercord. Process of decorating enameled metal. July 30, 1912. (180, 1162).

1,055,678. G. Spitz. Removing the enamel from scrap enameled metal. Mar. 11, 1913. *C. A.*, 7, 1593. (188, 379).

1,065,401. G. Spitz. Removing the enamel from enameled goods. June 24, 1913. *C. A.*, 7, 2845. (191, 862).

1,072,047. Walter L. Shepard. Process of making enameled articles. (194, 129).

1,091,492. H. G. Essayan. Enamel for metals. Mar. 31, 1914. *C. A.*, 8, 1861. (200, 1130).

Heating a mixture of 2 per cent silver, 8 per cent copper and 8 per cent lead, melted together with 82 per cent sulfur and powdering the product.

1,101,455. I. Kreidl. Composition for rendering white enamels opaque. June 23, 1914. *C. A.*, 8, 2932. (203, 1194).

Hydrated alkali zirconate, stannate, or titanate, combined with silica.

1,104,107. T. R. Davidson. Pickling metal to prepare it for enameling. July 1, 1914. *C. A.* 8, 3102. (204, 742). Also German patent 277,834. July 22, 1913.

Immersed in conc. sulfuric acid at 90–150 degrees, then washed with water at 65 and then at 100 degrees.

1,104,266. M. Mayer and B. Havas. White opaque enamel. July 21, 1914. *C. A.*, 8, 3106. (204, 896).

Contains spinel and preferably small amounts of zirconium, titanium stannic or silicon oxide as opaquing material.

1,104,679. I. Kreidl. Opaque enamel. July 21, 1914. *C. A.*, 8, 3196. (204, 940).

Contains colloidal zirconium oxide.

Reissue 13,791. I. Kreidl. Making an opaque material for white enamels. Aug. 25, 1914. *C. A.*, 8, 3494. (205, 1291).

Natural zirconium silicate is heated with 4 times its weight of sodium hydroxide to 500–600 degrees, washed, dried, and heated to a glowing temperature.

1,117,197. I. Kreidl. White enamel. Nov. 17, 1914. *C. A.*, 9, 136. (208, 682).

The opaquing material is formed of zirconium oxide combined with silica and about 3–4 per cent of alkali metal.

1,118,898. P. Eyer. Enamel glazing. Nov. 24, 1914. *C. A.*, 9, 136. (208, 1314).

1,119,905. C. A. W. Vollrath. Enamel for coating machine. Dec. 8, 1914. *C. A.*, 9, 239. (209, 381).

Finely comminuted colored glass in addition to the ordinary enamel to form a speckled coating.

1,123,760. I. Kreidl. Making a material for opaquing white enamel. Jan. 5, 1915. *C. A.*, 9, 701. (210, 193).

1,124,380. O. Zahn. Muffle furnace for enameling. Jan. 12, 1915. *C. A.*, 9, 701. (210, 454).

1,126,621. A. de Back. Recovering iron and steel from waste enameled articles. Jan. 26 1915. *C. A.*, 9, 592. (210, 1327).

1,128,691. I. Kreidl. Opaquing materials for enamels, glass, etc. Feb. 16, 1915. *C. A.*, 9, 1103. (211, 797).

Hydrates zinc oxide containing 2–7 per cent combined alkali and a few per cent of water, varying inversely as the amount of alkali.

1,129,300. I. Kreidl. White enamel. Feb. 23, 1915. *C. A.*, 9, 1103. (211, 1047).

The opaquing agent consists of zirconium oxide combined with a small amount of alkali.

1,140,105. Charles Bickmeier and Daniel A. Liston. Continuous-burning furnace for burning enamel ware. May 18, 1915. *J. Soc. Chem. Ind.* 34, 717. (214, 914).

1,150,467. J. Weber. Opaquing composition for use in vitreous enamels. Aug. 17, 1915. *C. A.*, 9, 2701. (217, 871).

Hydrates stannic oxide containing about 10 per cent water and 3–5 per cent of alkali.

1,150,772. I. Kreidl. Opaquing material for white enamels. Aug. 17, 1915. *C. A.*, **9**, 2701. (217, 976).

Alkaline compound of zirconium formed by treating with acid and washing to remove part of the combined alkali.

1,153,748. C. Baezner. Opaque enamel or glazing composition for use on sheet iron, etc. Sept. 14, 1915. *C. A.*, **9**, 3343. (218, 528).

1,178,469. H. G. Higley. Enameling iron. Apr. 4, 1916. *C. A.*, **10**, 1587. (225, 320).

The iron is immersed in a bath prepared from dilute sulfuric acid, ferric oxide and an enamel composition.

1,181,944. J. Weber. Coloring enamels. May 2, 1916. *C. A.*, **10**, 1701. (226, 286).

Neutralized anhydrous calcium stannate is used as an opaque coloring.

1,196,342. Alfred de Baek. Method of recovering iron, steel, and the like from waste enameled articles. Aug. 29, 1916. (229, 1393).

1,196,243. Alfred de Baek. Apparatus for disintegrating metal articles. Aug. 29, 1916. *J. Soc. Chem. Ind.*, **35**, 1012. (229, 1393).

1,197,618. Arthur W. Forbes. Enameling apparatus. Sept. 12, 1916. (230, 352).

1,203,409. R. Rickmann. White opaque enamels. Oct. 31, 1916. *C. A.*, **11**, 93. (231, 1446).

Small proportion of potassium antimoniate is added.

1,205,845. H. A. Biggar. Enameling composition for use on metals. Nov. 21, 1916. *C. A.*, **11**, 198. (232, 869).

A mixture of various asphalts, rosin, Portland cement, etc., is used.

1,220,253. M. Meyer and B. Havas. Opaque white enamels. Mar. 27, 1917. *C. A.*, **11**, 1735. (236, 937).

A mixture of titanium oxide and zirconium oxide is used for opaquing white enamels.

1,230,958. K. Wurga. Coating aluminium with vitreous enamel. June 26, 1917. *C. A.*, **11**, 2323. (239, 989).

1,239,112. H. Kretzer and A. Cappel. Opaque enamels. Sept. 4, 1917. *C. A.*, **11**, 3407. (242, 126).

The opacifying agent, *e. g.*, a compound of Zr, Ti, Si, Al, Zn, or alkaline earth metal, is added to the other ingredients of the enamel after they have been at least partially ground in a wet mill, together with substances which precipitate colloids, such as ammonium chloride, magnesium sulfate, or chloride, or sodium sulfate.

1,249,937. P. Eyer. Ground enamel. Dec. 11, 1917. *C. A.*, **12**, 414. (245, 469).

Ore containing cobaltic oxide, freed from sulfur and arsenic, is used to color the enamel.

1,256,455, 1,256,456. P. Eyer. Enamel for iron. Feb. 12, 1918. *C. A.*, **12**, 986. (247, 433).

White enamel for glass consisting of ruby glass, clay, eryolite and sodium carbonate.

1,268,778. John F. Dodge and Harry C. Allen. Enameling apparatus. June 4, 1918. (251, 200).

1,272,917. R. D. Cooke. Removing enamel from metal surfaces. July 16, 1918. *C. A.*, 12, 1917. (252, 670).

Treated first with HCl (10 per cent) at 70 degrees and then with 25 per cent NaOH at 70 degrees.

1,273,632. William Lindsay. Enameling powder distributor. July 23, 1918. (252, 887).

1,281,762. Frank J. Carpenter. Enameling apparatus. Oct. 15, 1918. (255, 508).

A plurality of contracting members for engaging the rims of articles to be enameled attached to a rotating shaft.

1,285,862. Stefan Wiester. Enamel oven. Nov. 26, 1918. (256, 729).

1,290,060. Albert J. Boland. Enameling furnace. Jan. 7, 1919. (258, 11).

1,290,580. W. J. Kohler. Marking enameled ware. Jan. 7, 1919. *C. A.*, 13, 780. (258, 136).

1,311,487. G. H. Benjamin. Enameling kiln. July 29, 1919. *J. Am. Ceram. Soc.*, 2, 852. (264, 772).

1,313,834. I. Rennerfelt. Electric furnace. Aug. 19, 1919. *C. A.*, 13, 2642. (265, 424).

The furnace is adapted to melting enamels in crucibles.

1,314,831. F. Preusser. Opaque enamels. Sept. 2, 1919. *C. A.*, 13, 2478; *J. Am. Ceram. Soc.*, 2, 927. (266, 71).

Relatively low content of the usual opacifying agents, such as tin or zinc oxide is used by suitable mixing with other auxiliary ingredients.

1,314,861. P. Eyer. Clouding composition for enamels. Sept. 2, 1919. *C. A.*, 13, 2748; *J. Am. Ceram. Soc.*, 2, 927. (266, 71).

Zirconium borate supersaturated with zinc oxide is used as a clouding material in enamels.

1,316,018. R. D. Cooke. Enameling sheet metal ware. Sept. 16, 1919. *C. A.*, 13, 2986. (266, 306).

Sheet steel is coated with oil and subjected to a drawing operation, the ware then is heated to remove the oil which produces a thin oxide coating on the metal, the enamel is then applied and baked.

1,332,058. C. Musiol. Enamel for metals. Feb. 24, 1920. *C. A.*, 14, 1204; *J. Am. Ceram. Soc.*, 3, 513. (271, 629).

Triple silicate of Al, Na, and Ca mixed with fluorides and coloring substances.

1,335,279. Paul Dupont. Enameling and annealing furnace. Mar. 30, 1920. (272, 804).

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NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

THE COMPOSITION OF LEAD GLASSES

By ROBERT J. MONTGOMERY

The subject of lead glasses includes more than half of the entire glass field and is too large to be covered adequately in one paper. The present discussion will, therefore, be confined to the typical lead glasses, which extend from the soda-lime glass to which lead is sometimes added to obtain better melting qualities, to the lead silicate which contains only lead and silica. This field may be visualized by referring to figure 1 which is a chart used in a previous paper entitled "Twenty-three Types of Optical Glass."¹ The average glass manufacturer does not think of his glass as having optical properties but it has never the less and these properties are probably the only ones which all glasses have in common which at the same time give a basis for a fairly well defined classification into groups.

Referring again to figure 1, in which the fields of the various types of glass are shown in their relation to the refractive index for the *D* line and the mean dispersion or *V*, we find at the left-hand the typical lead glasses. They start with the telescope flint (*V*-50 to 55 and index 1.510) and extend with increasing index and decreasing *V* until the densest silica flint is reached (*V*-25 and index 1.800). The extreme limit of this type being about *V*-19 and index 1.96. We must also include the ordinary crown and soft silicate crown in this list, as often small amounts of lead are used. Glasses aside from these which include barium and boric acid lead glasses will be omitted in this discussion.

Probably the best way to get the subject in mind is to give typical examples of the composition of each type of glass with its index and dispersion. This is done in table 1.

¹ *J. Am. Ceram. Soc.* 3, 404-410.

TABLE I

| Glass type | SiO ₂ | PbO | K ₂ O | Na ₂ O | CaO | As ₂ O ₃ | n _D | V |
|-----------------------------|------------------|------|------------------|-------------------|------|--------------------------------|----------------|------|
| 1 Ordinary crown..... | 69.3 | 0.0 | 19.2 | 0.2 | 10.3 | 0.3 | 1.5176 | 60.1 |
| 2 Soft silicate crown..... | 69.2 | 6.5 | 17.0 | 3.0 | 4.0 | .3 | 1.5151 | 56.6 |
| 3 Telescope flint..... | 68.2 | 13.1 | 2.0 | 16.5 | 0.0 | .2 | 1.5219 | 51.5 |
| 4 Extra light flint..... | 62.6 | 24.1 | 8.5 | 4.5 | .. | .3 | 1.5414 | 46.9 |
| 5 Ordinary light flint..... | 53.9 | 35.2 | 7.6 | 1.0 | 1.9 | .3 | 1.5805 | 41.9 |
| 6 Ordinary flint..... | 46.3 | 45.0 | 5.6 | 2.5 | .3 | .. | 1.6162 | 36.6 |
| 7 Dense flint..... | 41.7 | 50.5 | 3.5 | 4.0 | .. | .3 | 1.640 | 34.6 |
| 8 Extra dense flint..... | 33.0 | 62.7 | 4.0 | .. | .. | .3 | 1.735 | 28.5 |
| 9 Densest silica flint..... | 17.9 | 82.0 | .. | .. | .. | .1 | 1.9626 | 19.7 |

In expressing the composition of a glass the terms to use are hard to decide upon. Batch composition expressed in terms of carbonates or nitrates of the oxides used with sand at 100 is very misleading, as the actual amount of oxides present is obscure. The batch calculated to the oxide basis with sand equal to 100 or expressed in per cent is an improvement but does not give the molecular or combining weight relation between the various oxides. The calculation to the equivalent weight basis with the RO elements or SiO₂ as unity is quite laborious and is seldom done in the glass plant. The composition can be well shown graphically by plotting the batch proportions against the optical properties of the glass.

Composition on the Equivalent Weight Basis

In expressing the composition of silicates on this basis it is common practice to calculate the RO bases to unity and to state the results as follows: $1\text{RO} - x\text{Al}_2\text{O}_3 - y\text{SiO}_2$. Alumina only appears as an impurity in these glasses and may be disregarded. In expressing batch composition they are usually stated with sand as a constant say at 100 or 1000. To preserve the continuity of thought of proportions it is well to calculate SiO₂ as unity and express a glass as $x\text{RO} - 1\text{SiO}_2$ holding silica a constant as in the batch.

This study is based upon the composition of 32 glasses selected from a total of about 200 given in the references at the end of this paper or melts made in our glass plant. They represent present day practice as nearly as can be.

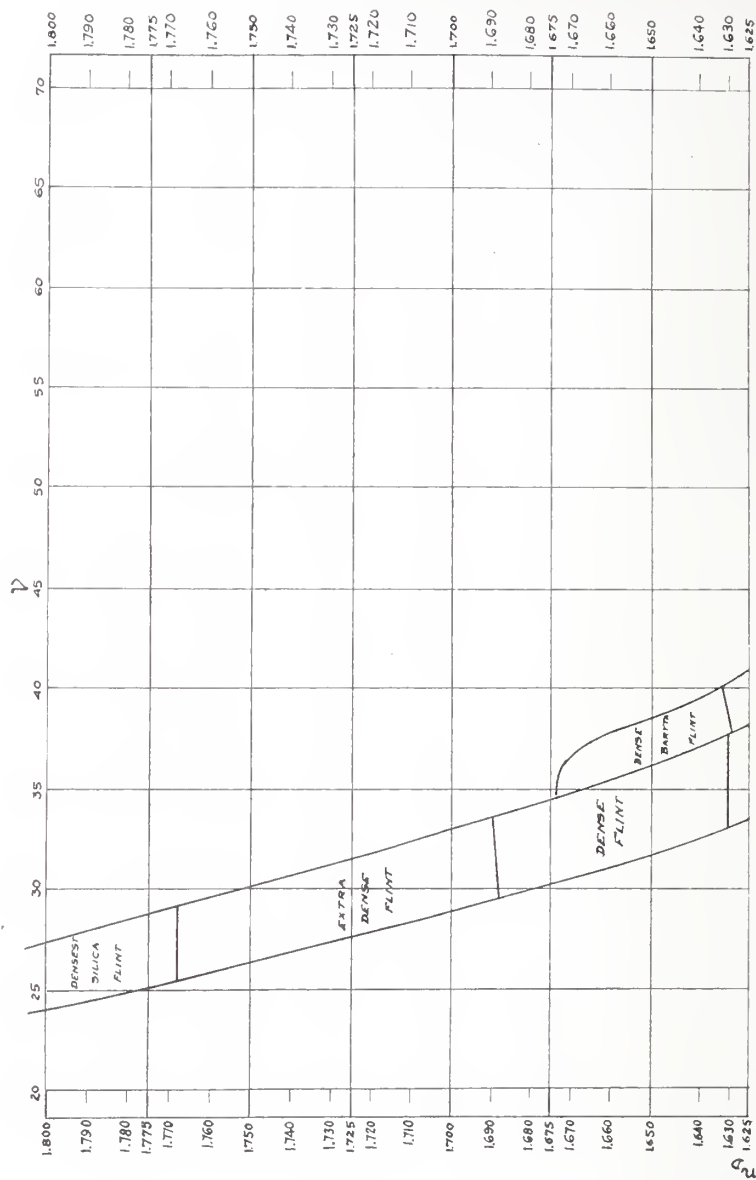


FIG. 1-A.

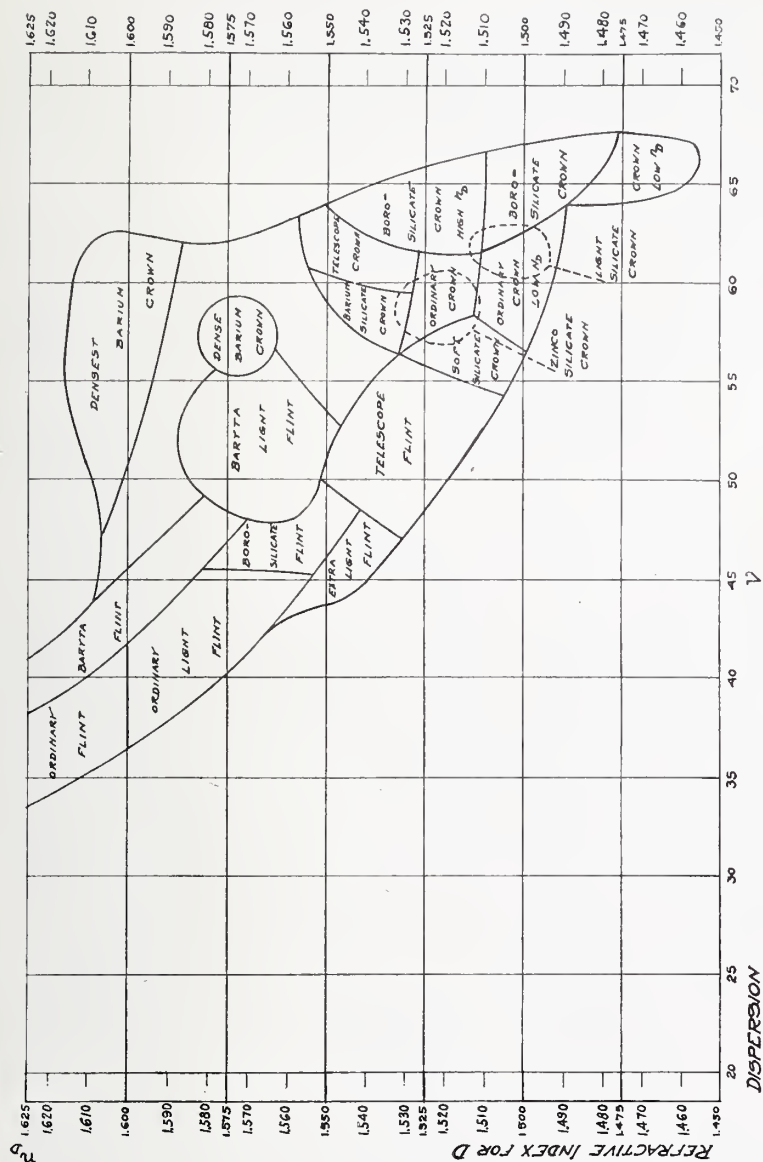


FIG. 1-B.

Molecular Composition vs. Index for the D Line.—In figure 2 the total RO content is given plotted against index. The thirty-two points plotted indicate the general trend. The minimum RO content is approximately 0.30 equivalents, when SiO_2

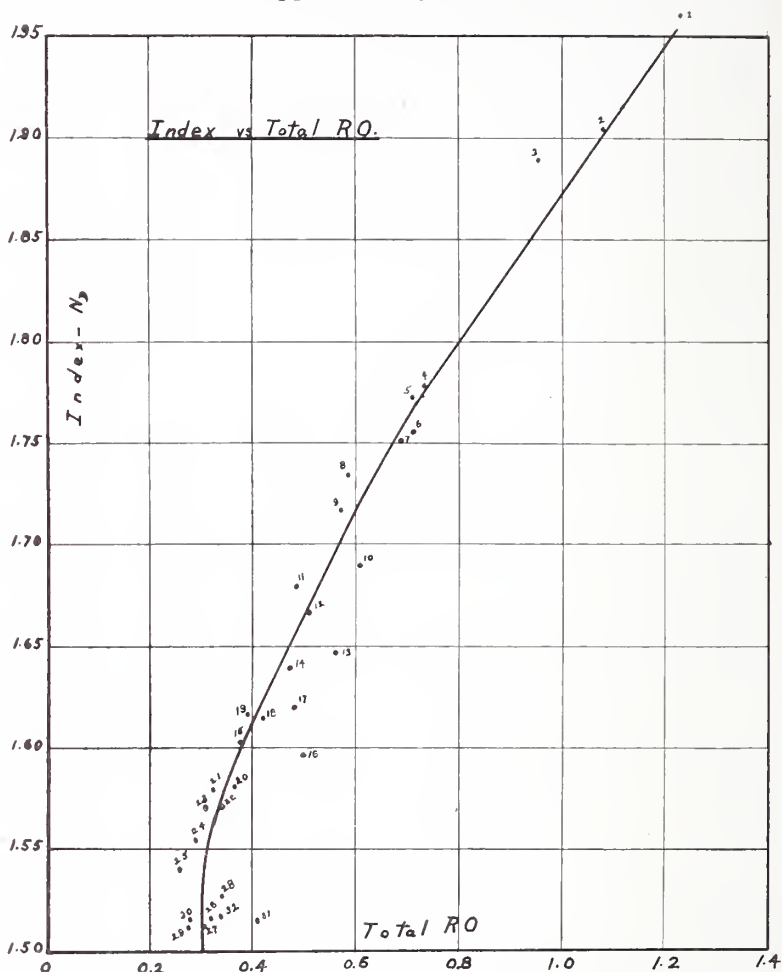


FIG. 2.

is unity. The line goes vertically until an index of 1.56 is reached and increases in a curve to about 0.8 equivalent RO with an index of 1.80. From there on it becomes practically a straight

line, until with an index of 1.95 it goes up to 1.22 equivalents. In figure 3 the lead content of the RO is indicated. The solid line curve starts at 0.0 PbO (points 32 and 31 are ordinary crown glass containing no PbO) and progresses along a straight line

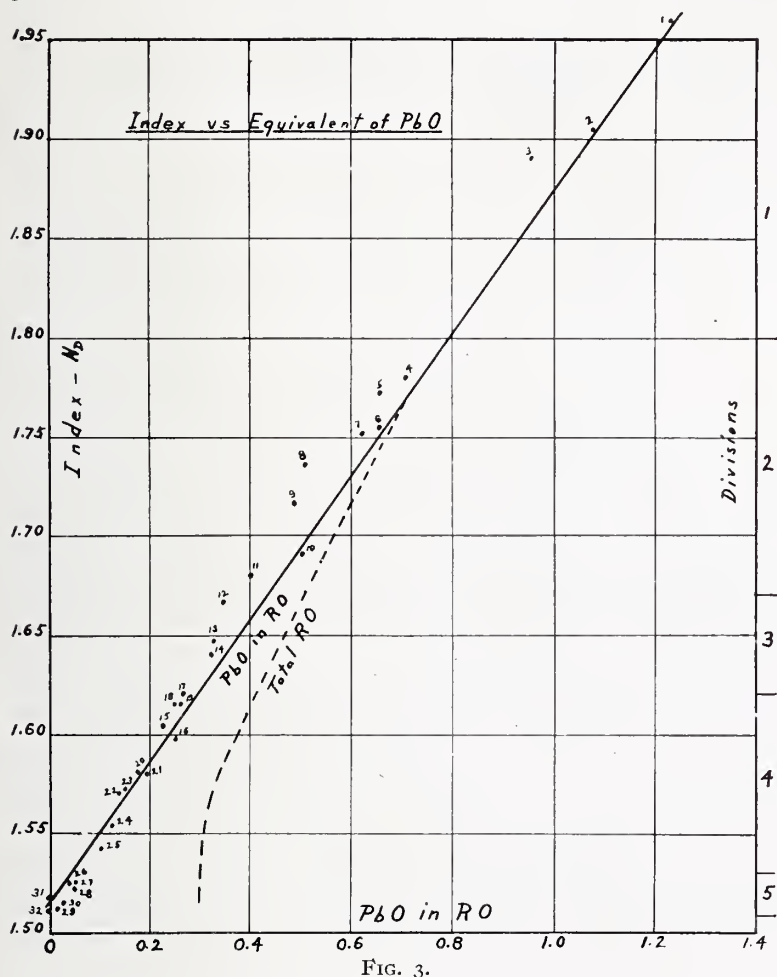


FIG. 3.

or very nearly so, till with an index of 1.95 we reach the same point as before, 1.22 equivalents PbO.

This total RO curve, as given in figure 2 is dotted in on figure

and shows that with an index of 1.8 or above (Division 1, figure 3) PbO is the only RO constituent and the glass formed is a silicate of lead. In Division 2, with an index from about 1.67 to 1.8,

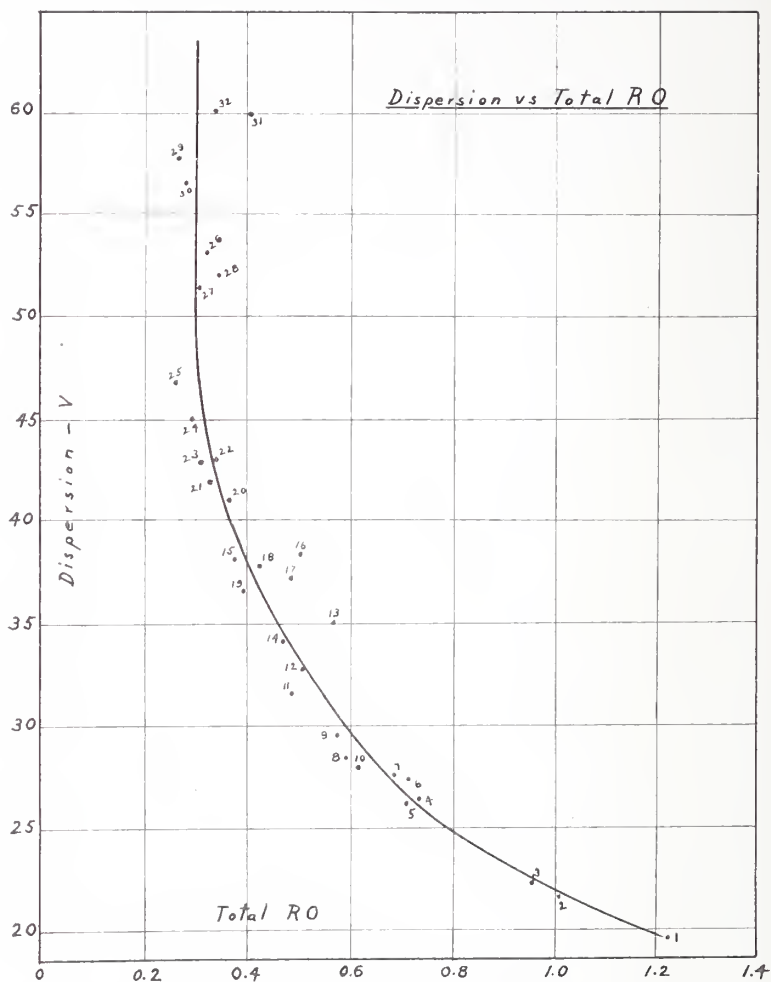


FIG. 4.

the usual RO is K_2O and PbO, the amount of K_2O being shown by the space between the solid and the dotted curve. In Division 3, Na_2O is often introduced and some times a small amount

of CaO is used. In Division 4, Na_2O and CaO are used in increasing amounts with a decrease in K_2O as the PbO decreases. The glasses are still primarily alkali-lead silicates, the CaO not

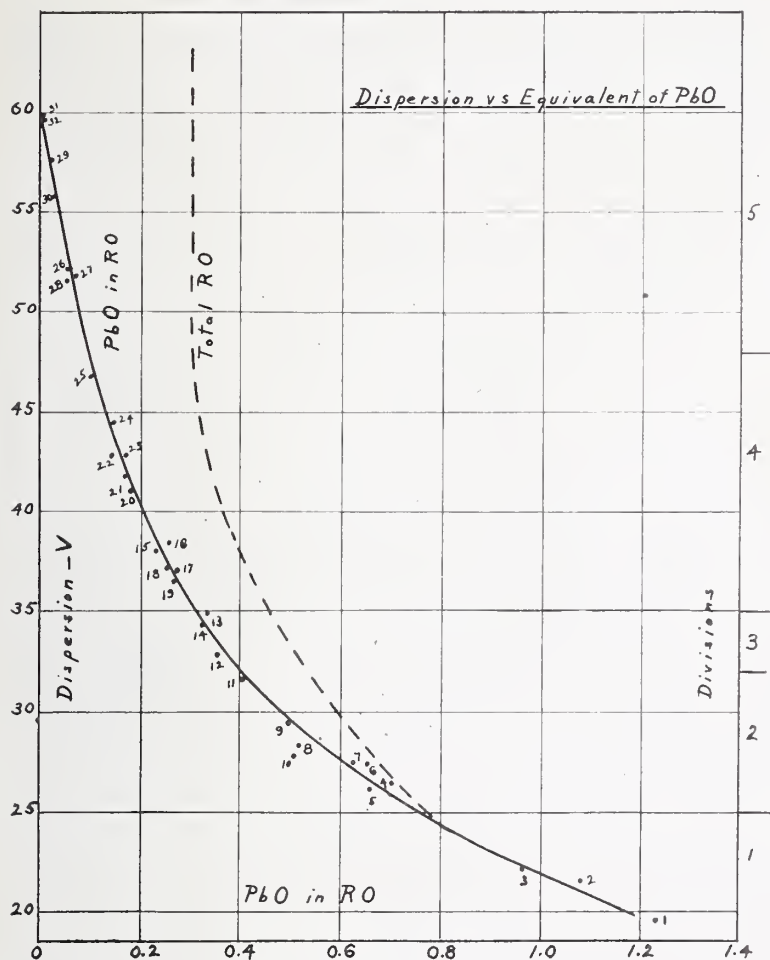


FIG. 5.

playing an important part. In Division 5, the glasses are essentially Na-Ca glasses with PbO added to obtain a higher index or better melting properties. K_2O in all these glasses tends to

give better color and melting qualities. Also in Division 5, ZnO may be used in fairly high amounts, up to about 0.05 equivalents. B_2O_3 is sometimes used to control the melting action.

Molecular Composition vs. Mean Dispersion or V.—In figure 4 the total RO content is given plotted against the mean dispersion. The thirty-two points again show very definitely the

Composition of Lead Glasses

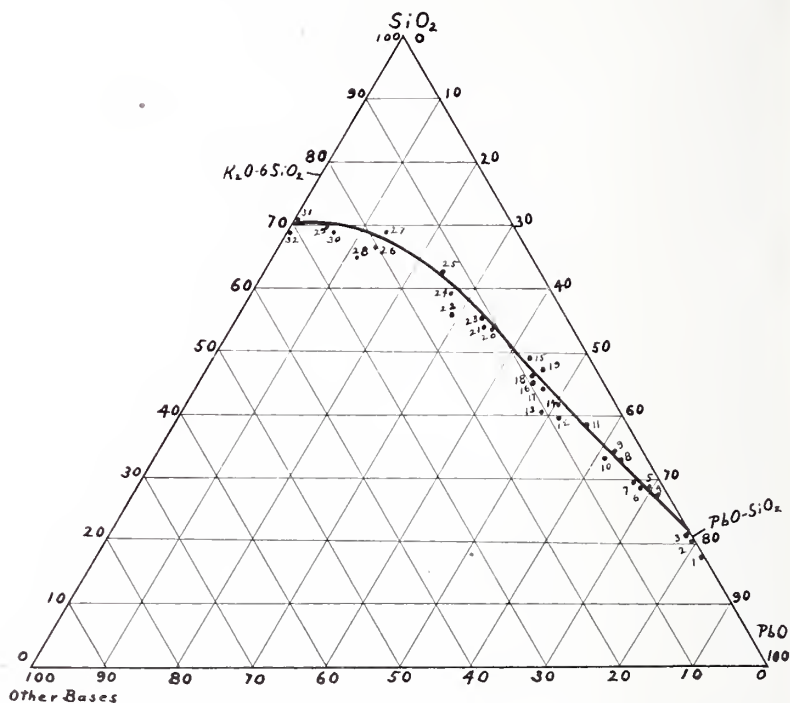


FIG. 6.

general slope of the curve. It is vertical as the V value drops from 60 to 48 and then curves off to the right as the V decreases to 19. In figure 5 the PbO content is indicated. The solid line gives the PbO content in the RO while the dotted line, taken from figure 4 shows the total RO. The space between indicates the

amount of other bases used and may be divided into five divisions as in figure 3. The divisions and oxides used are the same in both figures.

General Composition of Lead and Glasses

The fact that the RO varies from 0.3 equivalents to 1.2 equivalents where SiO_2 is unity, brings up the question of the molecular formula of these glasses. Typical lead glasses were plotted on the oxide basis by Major Fred E. Wright while he was at the Bausch and Lomb plant (unpublished notes). When the glasses were plotted on a triaxial diagram, using SiO_2 , PbO and K_2O plus Na_2O as the three components, he found that practically all fell near or on a straight line from PbO-SiO_2 to $\text{K}_2\text{O-6SiO}_2$. In figure 6 the thirty-two glasses were plotted, and it is seen that all lead glasses containing any considerable quantity of PbO fall near the line given by Major Wright, but as the PbO decreases below 20 per cent of the total batch (oxide basis) it curves off to the left and ends with not over 70 to 72 per cent SiO_2 in the glass. This gives a lower silica content than $\text{K}_2\text{O-6SiO}_2$ and is nearer to RO-3SiO_2 . The difference between the results obtained by Major Wright and myself is due to including glasses of a lower lead content. Calcium oxide and zinc oxide were included with K_2O and Na_2O when the glasses were plotted so as to take in the extreme of the lead glass series which is the ordinary crown glass containing no lead.

It is interesting to speculate as to the proportions of the basic oxides and silica, either free or combined in these glasses. Lead glasses in the molten state might be considered as a solution of the component oxides, which are SiO_2 , PbO , K_2O , Na_2O , CaO and in some cases BaO and ZnO . It would be a true solution if the oxides were miscible in all the proportions which occur in the glasses under consideration, but this is not the case. Glasses containing more than 15 to 20 per cent PbO have a decided tendency to give a layer in the bottom of the pot having a much higher lead content than the rest of the pot. Mechanical stirring has to be resorted to to keep the pot homogeneous. When a pot is properly stirred the glass will be optically homogeneous and free from any separation which can be detected. Therefore, while

we can not call high lead glasses true solutions they are mechanical mixtures of solutions so well mixed that they may be considered as uniform in composition throughout the mass. A glass then is a mixture of silicates of Pb, K, Na, etc. Each of these have a certain solubility in the others and must carry in solution any excess of silica present, since undissolved silica would not be fluid at ordinary furnace temperatures. We would like to determine the amount of this excess SiO_2 and must, therefore, consider how much silica would combine with the basic oxides present provided the mass was cooled slowly enough to allow the most easily formed silicates to crystallize out. In a number of cases crystals have been reported in glass and identified. We are interested in the following oxides: SiO_2 , BaO, CaO, Na_2O , K_2O and PbO.

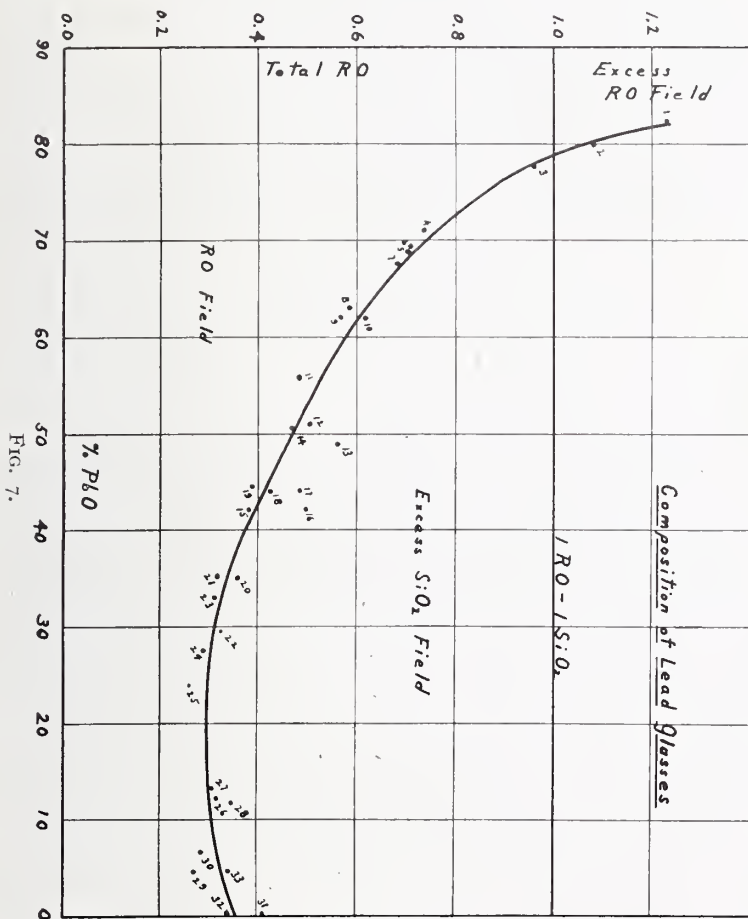
SiO_2 has often been reported as crystallizing in lead glasses. Bowen (*J. Amer. Ceram. Soc.*, **2**, 276) reports a surface film on a medium flint glass of silica. Fenner and Ferguson (*J. Amer. Ceram. Soc.*, **6**, 468) reports the formation of crystals of cristobalite as a cause of milky in a light flint glass. In our laboratory we often detect the presence of SiO_2 crystals as a surface film on flint glass during pressing. We may assume then that the silica is present in most of these glasses in excess of the amount required to form silicates of the various bases and if given the opportunity to crystallize it will do so readily.

Barium has been reported by Bowen (*J. Amer. Ceram. Soc.*, **2**, 273) as crystallizing in the form of $\text{BaO} \cdot 2\text{SiO}_2$ so we may assume this is the compound most easy to form, when an excess of SiO_2 is present. We are, however, not discussing barium lead glasses in this paper. In the same paper, Mr. Bowen states that CaSiO_3 or $\text{CaO} \cdot \text{SiO}_2$ is the form which will tend to crystallize out of a mixture containing an excess of silica. Rankin and Wright show this in their study of the Ternary system of $\text{CaO} \cdot \text{Al}_2\text{O}_3 \cdot \text{SiO}_2$ (*Amer. J. Sci.*, **39**, Jan. 1915).

To my knowledge lead does not tend to crystallize from a glass as a silicate, but the form which must be present is $\text{PbO} \cdot \text{SiO}_2$ (if a compound is actually formed in the molten glass). Segerblom in "Tables of Properties of Inorganic Substances" gives only one silicate of lead and this is $\text{PbO} \cdot \text{SiO}_2$. Segerblom also gives the normal sodium silicate as $\text{Na}_2\text{O} \cdot \text{SiO}_2$ and for potassium,

K_2O-SiO_2 . We may assume that these are the forms which might be present in an ordinary lead glass melt. Making a list we have: $PbO-SiO_2$, K_2O-SiO_2 , Na_2O-SiO_2 , $CaO-SiO_2$, $BaO-2SiO_2$. They are all metasilicates with the exception of barium silicate.

Referring back to figure 3 we note that in soda lime glasses



(Division 5) the total RO is 0.3 with SiO_2 as unity, so we must have 0.7 equivalents of SiO_2 as free silica. At the other extreme (Division 1) we find the lead as high as 1.2 $PbO-1.0 SiO_2$ which shows an excess of 0.2 equivalents PbO over the compound $PbO-$

SiO₂. These relations are shown graphically in figure 7 where the total RO is plotted against the PbO content of the glass. The thirty-two representative glasses are plotted and a heavy horizontal line is drawn at the point 1RO-1SiO₂. The glasses plotted certainly show the general shape of the curve. The space below the curve shows the total amount of the bases expressed as equivalents and may be called the RO field. The space between the curve and the 1RO-1SiO₂ line gives the amount of excess silica in equivalents which must be taken into solution. With about 78 per cent PbO and above the proportion is greater than 1RO-1SiO₂. These glasses are lead silicates containing no alkali and contain an excess of PbO which the PbO-SiO₂ must take into solution to give a glass.

REFERENCES

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2. "Jena Glass," by Hoverstadt.
3. Williams and Rand, "Procedures in the Manufacture of Optical Glass," *J. Amer. Ceram. Soc.*, 2, No. 2, p. 422.
4. Fenner, "The Technique of Optical Glass Melting," *J. Amer. Ceram. Soc.*, 2, No. 2, p. 102.
5. Allen and Zies, "A Contribution to the Methods of Glass Analysis," *J. Amer. Ceram. Soc.*, 1, No. 11, p. 737.

BAUSCH & LOMB OPTICAL CO.
ROCHESTER, N. Y.

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

A VERMILION COLOR FROM URANIUM*

BY CHARLES F. BINNS AND FROBISHER LYTLE

Not very much appears to have been written upon the subject of uranium oxide as a colorant, though the production of uranium blacks under reduction, and yellows under oxidation, has long been practised, especially by porcelain decorators.

Three papers have been published in the Transactions of the Society, one by Riddle in Volume VIII, the second by Minton in Volume IX, and the third by Koener in Volume X, the last referring especially to uranium bismuth crystals.

Riddle quotes Cunninghame in "The Art of Enamelling on Metals" to the effect that the yellow oxide of uranium "has a feeble coloring power," a statement which Riddle controverts by showing that, fused with lead compounds, uranium produces a rich orange. Minton, in discussing Riddle's contribution, confirms this statement and further points out the variations which accrue when different oxides of uranium are used.

The present experiment was inspired by the accidental development of a peculiarly rich vermilion red almost a scarlet.

The problem undertaken was the production of greens for terracotta under open kiln conditions, without the use of copper or chromium as colorants. A triangle was plotted, of which the angles were a cobalt blue, a uranium yellow, and a colorless glaze containing zinc oxide. The base of the triangle, of which one extremity was the uranium color, and the other the zinc glaze, afforded several examples of a rather vivid orange, and it was decided to pursue this line of investigation.

Two glazes were made, corresponding to the formulas:



To the batch was added 20 per cent commercial yellow oxide of uranium (sodium uranate) and the whole was fritted.

* Received Feb. 27, 1920.

This corresponds approximately to the mixture:

| | |
|--------------------|-------|
| Red lead..... | 57 |
| Feldspar..... | 20 |
| Zinc oxide..... | 2 |
| Flint..... | 12 |
| Uranium oxide..... | 9 |
| | <hr/> |
| | 100 |



To this was added 37 per cent of the same uranium oxide and the whole was fritted, except the necessary amount of clay.

Glaze No. 1 was the bright vermilion color, but this did not appear in No. 2, which seems to indicate that the amount of uranium present must not greatly vary.

The texture of the glaze has not yet been fully investigated. Probably the absence of luster is due to insufficient temperature. These glazes were fired in closed saggars and not in the open kiln, the heat treatment being cone 04 for VO and cone 02 for VI.

Some difficulty has been experienced in protecting the uranium oxide from reducing influences, but with complete oxidation these vermilion colors seem to be a commercial possibility.

NEW YORK STATE SCHOOL OF CLAYWORKING AND CERAMICS
ALFRED, NEW YORK

NOTICE.—Further discussion of this subject is solicited. All communications should be sent to the Editor.

ARTIFICIAL *versus* NATURAL DRAFT IN DOWNDRAFT PERIODIC KILNS¹

BY AUGUST STAUDT

I have requested a discussion on artificial *versus* natural draft for the following reason. Having lost my head burner about a year ago and not knowing of another man to take his place, I temporarily assumed the duties myself in order to become better acquainted with the trials and tribulations of burning ware successfully, and also to ascertain why the results of burns are sometimes so varied. It did not take me very long to find that the atmospheric conditions were the principal cause of the trouble, inasmuch as the firing of the kilns had at all times been attended to very conscientiously.

Our kilns are of the ordinary pottery-kiln type, up and down draft, connected to a common stack draft, regulation by means of a damper in the stack. I observed that on a clear and windy day it never took me more than five to six hours to finish a kiln, knowing at the same time that the burn would be good, whereas on a damp, foggy or sultry day it took as long as eleven hours. In a troublesome finish of this kind I could not venture any advance guess as to results. The finishing time is reckoned from the period of cone 9 starting to move until cone 11 is half down.

This leads me to believe that if I could create in the stack a given uniform draft by means of perhaps inserting a fan I should be reasonably sure of uniform burns at all times. I shall be very glad to have the opinion of members of our Society.

PERTH AMBOY TILE WORKS
PERTH AMBOY, N. J.

Discussion

MR. R. T. STULL: There is no question but what forced draft is of great assistance in certain cases, especially where the kilns are improperly designed as to proportions, grate areas, and so forth. I am not referring so much to the updraft pottery kilns.

¹ Received February 27, 1920.

as to the downdraft kilns used by the manufacturers of structural materials. A great many of the earlier kilns were built by men who knew nothing about the theory of combustion, the laws governing the expansion of gases, proper sizes of fire boxes, flues and stacks and who did not take these factors into their calculations. In other words they did not always use engineering data.

I have in mind one plant where, in order to finish their kilns, it was necessary to choke the fire boxes full of coal and work like beavers for three or four days before they were able to get their temperature. In order to attain the temperature required it was also necessary to use high grade Pittsburgh coal, shipped quite a long distance, because local coal would not give the temperature. They installed a forced draft system which enabled them to save considerable time and to use the cheapest kind of coal. The natural draft was not sufficient to overcome the resistance in friction, but by using forced draft under the grate they were able to get their temperature in the shortest possible time. Their figures showed that they saved two dollars a thousand on burning paving brick over the old system. Part of that saving was made by using cheaper coal. I have in mind another plant that was taking eleven days to burn paving brick, and by using forced draft burned them in six and a half days.

PROF. C. F. BINNS: I think we are apt to get into trouble by mistaking the matter of draft and considering it inversely. We are apt to think of draft as suction, whereas draft is really nothing but pressure. If we think of it from that point of view, we shall get more light on it.

MR. F. B. ORTMAN: I have great sympathy with Mr. Staudt in his trouble with draft. We encountered some difficulty in some of our kilns located where they were completely surrounded by buildings higher than the stack. We seriously considered the introduction of forced draft, but before going to that trouble, we thought we might be so near to the required stack diameter and height that we could correct the trouble by merely enlarging and raising the stack. We did this and corrected the trouble on those particular kilns. It was surprising, very surprising to me, to see how much difference an extra six inches in the diameter

of the stack or an extra fifteen feet in height made in the condition of those particular kilns.

MR. HERBERT FORESTER: I should like to say that I had a chimney in England, about two hundred feet high, and a number of downdraft kilns were worked by this stack. Some of the kilns were over one hundred feet away from the foot of the stack; but we never had any trouble, as the draft was exceedingly strong, even when apparently there was no wind.

I have found when visiting many of the potteries and brick plants here that the chimney stacks being too low is the cause of a very great deal of trouble; and if these gentlemen will raise their stacks, I am certain the trouble will be obviated. I have personally recommended at many plants the raising of the stacks; and without exception, the desired result has been obtained. In some cases, pottery kilns that were taking 140 hours to fire are now fired in 95 hours. In the case of brick firing, the time has been reduced from 10 to 7 days, and the quality of the products has been greatly improved.

I would also like to mention that when you have several kilns working into the same stack at the same time, it is a good plan to build a wall about twenty feet high up the center of the inside of the stack, since this will obviate any back draft.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

PRODUCER GAS AS FUEL FOR THE GLASS INDUSTRY*

BY F. J. DENK

Discussion

MR. W. W. OAKLEY: The paper by Mr. Denk is very interesting to those of us who are intimately connected with the thermodynamic phases of the glass industry. Some of the types of construction he advocates are different from those generally used, yet in those cases the present practice can only be considered as the best in the light of present knowledge and is very far from perfect.

The calculations given for the operating cost of a plant using oil as against those of a plant using producer gas are very interesting. There is another question involved, however, which is as interesting and in most cases far more important under present manufacturing conditions, namely, the question of storage capacity. Both coal and oil are difficult to obtain in regular quantities due in the case of coal to mining and transportation difficulties, and in the case of oil to transportation difficulties and a high demand. There can be no question but that a plant at present should have a fuel supply on hand at all times sufficient for at least a three weeks' continuous run. The writer would not allow this supply to get below a minimum of six weeks. On the basis of the large plant in question this would require the storage of 3150 tons of coal. This if piled at an average height of 12 feet would require a storage space equivalent to 50 by 200 feet. On the same basis storage capacity for 462,000 gal. of oil would be required. Obviously this would be a very expensive proposition not worthy of further discussion. Consequently, when comparison is made of oil and producer gas costs it is generally understood that the risks to continuous operation are by far the greatest with oil. Furthermore when the oil supply does fail, the manu-

* The paper appears on pages 94 to 113 of this volume of the Journal.

facturer is helpless, his only recourse being auxiliary coal fire-boxes. If in the case of gas producers his coal supply fails, it is generally possible to locate a sufficient supply of some sort of coal to keep running until the regular supply is available.

The statement is made in the paper that if the labor supply available is of low grade, hand-poked producers should be installed. If a higher class labor is available, automatic producers are better. The truth of this statement can only be appreciated by the engineer who has tried handling mechanical producers in times of labor shortage. Due to the high rate of gasification in these producers, 35 lbs. of coal per sq. ft. of cross sectional area per hr. as compared with 12 lbs. per sq. ft. of cross sectional area per hr. in the case of the hand poked, a mechanical producer if allowed to get out of adjustment for a very short period due to ignorance, will get into such bad shape as to make a poor grade of gas for periods of several hours. The hand-poked producer on the other hand running at a slower rate will not get into bad shape so rapidly and consequently will give the fireman more time to correct the condition. Furthermore, only one-third of the gas plant will be in bad shape at a time under the latter conditions.

Mention is made of the use of low-grade coal. Unless a very intelligent operator is available changes in coal should be made very cautiously as complete changes in adjustment are required for making equal amounts of gas from different coals. This is especially true of mechanical producers. For the greatest reliability when no spare unit is available, a mechanical producer 10 ft. in diameter should not be expected to gasify more than 2300 lbs. of good coal per hour.

In connection with the question of loss of sensible heat in the gas while passing through the mains a temperature drop of 500°F. in 150 ft. of main is given. In the case of an overhead main lined with insulating brick this drop is only 180° in 380 ft. Consequently the question of main location is only one of cost.

The writer believes that if more papers like this one could be given, much fuel and needless construction expense would be saved in the design and operation of producer gas plants in the glass industry.

AUTHOR'S REPLY: Mr. Oakley's discussion forms a very valuable addition to my paper. Some of the points, he has brought forth, have not been mentioned by me for the reason given before I started to read the paper, *viz.*, that my remarks were intended chiefly for the owners and managers of small and medium sized plants. With such plants it is, in many cases, a question of space, when it comes to storing coal. Wherever it is possible, I advocate the laying-in of coal reserves, but this can not be done under all conditions; it is almost always impossible in old factories, while in new layouts space for storing coal should be provided. With modern methods, the danger of instantaneous combustion is practically eliminated, but some factory managers still advance this as a reason for their objection, basing these objections on former actual conditions. This was another reason, that I did not say anything about coal storage, as I would have had to go too far into details.

The remarks about the interrelation between cheap labor and type of producers prove completely the correctness of my statement. I know of several cases, where factory managers were induced to buy mechanical producers on account of the higher rate of gasification, but who did not believe that this was offset by the trouble due to their low-grade of operators, until they found it out by themselves.

What I have said in regard to the use of low-grade coal was not meant in the sense of changing from a high grade to a low grade of fuel in the same producer. I stated, "that they (*i. e.*, the mechanical producers) can gasify low grades of coal better than the other type," which, then, is followed by a remark taken from the U. S. Geol. Survey's Bulletin on "Coal in 1917," to show why our coal is, at present, of a lower grade than it used to be. What I wanted to say was, that for a mechanical producer it was not necessary to get as high a grade of coal as for a hand-poked producer to obtain as good results.

The question of covering the pipe to retain as much of the sensible heat as possible is surely one of cost. But here it is where the trouble comes in with managers of small or even medium sized plants. The first cost is the main item in these cases, and the producer plant should, therefore, be located in such a way,

that the best results will be obtained with the least outlay of money. One case, however, I remember, where I wanted the lines covered—having about 270 ft. of the main gas flue outside the factory building or cover—the concern being well able to stand the increase in cost; but the manager objected, saying, that covering would make the inside so hot, that the lining would melt. There was, of course, no use trying to convince the gentleman that the covering did not generate heat, but that it was only supposed to conserve that comparatively little heat which was in the gas.

HOUSE BUILDING,
PITTSBURGH, PA.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

CERAMIC ABSTRACTS ¹

General

The post-war status of the Ceramic Industries. A. V. BLEININGER. *Chem. and Met. Eng.* **23**, 630 (1920).—An outline of the need for reducing the fuel consumption and for the introduction of labor-saving devices, with a short review of the economic status in the manufacture of the various clay products.
A. E. MALCOLM.

Cement for porcelain. ANON. *Keram. Rundschau*, **28**, 218 (1920).—Cements for cementing porcelains and metal are as follows: (1) Ground fluorspar, glass powder and water glass. (2) Litharge with glycerine. (3) A thick glue mixed with $\frac{1}{2}$ part of boiled linseed oil. (4) Zinc oxide, calcined magnesia and water glass in equal parts. This mixture is dried slowly. (5) Chalk and powdered zinc mixed in equal parts with water glass. (6) 20 parts plaster of paris, 50 fine ground flint and 30 zinc oxide. This mixture is mixed with water glass to a thick paste.
H. G. SCHURECHT.

Dental porcelain filling. ANON. *Keram. Rundschau*, **28**, 22-3 (1920).

In porcelain fillings the dentist obtains the filling in the form of a powder. This is mixed with water and pressed into a cavity. In drying soluble salts come to the surface and form a protective coating for the filling. The chem. analysis of one type is as follows: SiO_2 71.10, Al_2O_3 12.12, TiO_2 0.20, Fe_2O_3 0.28, CaO 1.10, K_2O 11.30, Na_2O 1.88, loss on ignit. 1.84.

Mineral composition:

| | | | | | |
|-------------------|-------|------|-----------------------|-----------------------------------|--|
| Feldspar..... | 89.50 | 0.70 | K_2O | } 0.700 Al_2O_3 { | 6.840 SiO_2 0.014 TiO_2 |
| Sodium carb..... | 4.00 | .18 | Na_2O | | |
| Calcium carb..... | 2.70 | .12 | CaO | | |
| Quartz..... | 3.80 | | | | |

A more fusible porcelain is as follows: SiO_2 69.58, Al_2O_3 11.32, TiO_2 0.16, Fe_2O_3 0.28, B_2O_3 0.30, CaO 2.40, K_2O 11.82, Na_2O 1.74, loss on ignit. 2.30.

| | | | | | |
|---------------------|-------|-------|-----------------------|-----------------------------------|---|
| Feldspar..... | 61.06 | | | } 0.565 Al_2O_3 { | 5.90 SiO_2 0.023 B_2O_3 0.011 TiO_2 |
| Potassium carb..... | 1.98 | 0.638 | K_2O | | |
| Sodium carb..... | 1.98 | .141 | Na_2O | | |
| Calcium carb..... | 4.21 | .221 | CaO | | |
| Borax..... | 0.83 | | | | |
| Quartz..... | 29.07 | | | | |

¹ The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of Chemical Abstracts by cooperative agreement.

A very fusible mixture use for fillings and for enamel is as follows: SiO_2 68.14, Al_2O_3 2.20, Fe_2O_3 —, TiO_2 trace, B_2O_3 10.60, CaO 0.80, K_2O 6.94, Na_2O 10.08, loss on ignit. 1.15.

| | | | | | |
|-----------------|-------|----------------------------|-----------------------------------|---|--|
| Feldspar | 12.02 | 0.295 K_2O | } 0.086 Al_2O_3 { | { | 4.544 SiO_2 0.706 B_2O_3 |
| Sodium carb. | 7.90 | .650 Na_2O | | | |
| Potassium carb. | 7.21 | .055 CaO | | | |
| Borax | 10.95 | | | | |
| Calcium carb. | 1.43 | | | | |
| Quartz | 60.49 | | | | |

H. G. SCHURECHT.

Refractories

Note on the tensile strength of refractory materials. MORRIS W. TRAVERS. *J. Soc. Glass Technology*, 4, 138-9 (1920).—In many places in furnace construction and especially in pot walls, tension and not compression is the important property. Changes which increase resistance to load may have a very different effect on tensile strength. The theory that an ideal refractory should consist of a very high percentage of infusible material, carefully graded and bonded with a very small quantity of vitreous bond may be justified from the standpoint of resistance to load, but it does not follow that tensile stresses will be equally well withstood. The ideal refractory consists of a system of interlocking crystals formed *in situ*, in a glassy matrix. If the matrix is such as to form a sillimanite layer in contact with alkaline fluxes, then corrosion by glass is largely avoided, for such a layer greatly delays the mixing of the liquid phases on either side of it.

C. H. KERR.

The casting of pots for use in experimental work on optical glasses. ALICE B. TAYLOR. *J. Soc. Glass Tech.*, 4, 140-52 (1920).—The water content of a pot mixture for casting should be about 20%. The experimental pots cast were only 9" in diam. The mixture was 3 parts china clay to 2 parts of grog, burned to conc 18 and sieved to 20 mesh (sometimes 30 mesh). Sodium carbonate and sodium silicate, $\frac{1}{8}$ of 1% each, were added. Casting under the pressure of a column of slip being fed in at the center of the bottom developed ring cracks in the bottom. Casting under air pressure and with the slip fed in at the center of the bottom was satisfactory. A pipe from the pressure tank containing the slip led up to the bottom of the pot mould. The initial air pressure for these small pots was 20-25 lbs. per sq. in. After filling the pressure was reduced to 10 lbs. and kept there for 45-60 min. until the pot had solidified, when it was taken from the mould to complete the drying. The best casting was obtained with slip density of 1753 grams per liter. Distribution of grog through the pot wall was studied by taking air-dried fragments from various locations; heating them up slowly to about 500° C., then rapidly in a blowpipe to about 100-200° C. below the temp. of calcination of the grog. These fragments were then ground on a carborundum wheel, then on fine carborundum and emery and finally polished on a pad with rouge. The grog particles then stand out plainly.

C. H. KERR.

The composition, drying and firing shrinkage, porosity and density of British fireclays suitable for glass furnace refractory materials. *J. Soc. Glass Technology*, 4, 162-204 (1920).—Twenty-seven clays from mines in England, Wales and Scotland were examined and detailed information is given in tabular form. Burning tests were carried up to 1400° C. No relation was found between chemical composition and the amount of water required to make a plastic mass. Rational composition, as calculated from the ultimate composition, was of no value in correlating any relationship between properties and mineral constitution. The tests indicate that the provisional specifications of the Refractories Research Committee of the Soc. of Glass Technology are too drastic to permit the use of many, if any, of the British clays. The aluminous clays were, in general, much more difficult to work than the siliceous clays. Most of the clays showed expansion at 500-900° C., but those high in alumina did not. In general, the clays showing a wide range of porosity were high in alumina and relatively high in the fluxes, lime, magnesia, potash and soda—the siliceous clays showed a narrower porosity range. When fluxes exceeded 2% the firing shrinkage above 750° was marked and the porosity range wide. C. H. KERR.

Sintered dolomite. ANON. *Tonind.-Ztg.*, 44, 519 (1920).—A dolomite suitable for sintering contained 32-42 % MgO, 0.73% Fe₂O₃ + Al₂O₃ and 1.34-1.9% SiO₂ (The technical use of lime, Kosmann, p. 91, 1919). Bloek (Das Kalkbrennen in Schachtofen mit misceuerung, 127 (1917)) describes a process for sintering dolomite in a cupola furnace. A description of furnace is given in *Tonind. Ztg.*, 1907, p. 659 also in 1910, No. 126, 1913, no. 107, p. 1397. A plant for making dolomite brick is described in 1902, p. 2006.

H. G. SCHURECHT.

PATENTS

Method of shrinking magnesia. LEWIS E. SAUNDERS. U. S. 1,352,388, Sept. 7, 1920. An electrical method of shrinking magnesia, which consists in locally heating a charge of magnesia under conditions to establish a current path therethrough, and progressively shrinking further portions of the charge by means of an electric current traversing the conductive portions of the magnesia.

C. M. SAEGER, JR.

Glass

The calculation of the relative expansion of glass. LUDWIG SPRINGER. *Sprechsaal*, 53, 193-5 (1920).—The discussions deal especially with the problem as it is related to the making of flashed glass. One of the most effective ways of governing expansion coefficient is in the substitution of boric acid for silica or vice versa the boric acid additions causing decreases in coefficient. The Winkelmann and Schott factors used for calculating the coefficient of expansion are: soda, 10.0; potash, 8.5; lime, 5.0; alumina, 5.0; barium oxide, 3.0; lead oxide, 3.0; arsenic, 2.0; zinc oxide, 1.8; silica, 0.8; magnesia, 0.1; boric acid, 0.1. (Note by abstractor: There seems some doubt

as to the accuracy of these figures. See abstract, *J. Am. Ceram. Soc.*, **3**, 592.) Mayer and Havas derived the following factors in addition as applying especially to enamel-making materials: cryolite, 7.4; sodium fluoride, 7.4; feldspar, 2.5; chromium oxide, 5.1; cobalt oxide, 4.4; nickel oxide, 4.0; ferric oxide, 4.0; antimony oxide, 3.6; manganese dioxide, 2.2; copper oxide, 2.2; zirconium oxide, 2.1; tin oxide, 2.0. One noteworthy difference is in the comparison of arsenic and antimony. Experiments with a soda lime glass to which was added $2\frac{1}{4}\%$ of antimony oxide based on the melted weight, showed 1.6% antimony in the finished glass—a loss of about a quarter of the antimony. A similar experiment with a potash-lead glass having 1.9% of antimony oxide, based on the melted weight, showed only 0.8% in the finished glass, somewhat over half having volatilized. The arsenic is quite volatile. Fluorine shows considerable variation in the amount that volatilizes out, varying from about 20 to about 33% of that added. In enamels about 10 to 16% of the fluorine goes off. An example of the expansion calculations follows: A white base glass made from the mixture: sand, 100; marble, 20; potash (80%) 35; would analyze: SiO_2 , 77.0; CaO , 8.4; K_2O , 14.6. The expansion number calculated from the above factors is: $77.0 \text{ SiO}_2 \times 0.8 + 8.4 \text{ CaO} \times 5.0 + 14.6 \text{ K}_2\text{O} \times 8.5 = \text{total } 227.7$. A silver yellow flash glass to be used with this white base glass is made from the batch: sand, 100; red lead, 70; potash (80%), 30; saltpeter, 5; silver nitrate, 1. The analysis is: SiO_2 , 53.5; PbO , 36.3; K_2O , 10.0; Ag , 0.3. The expansion factor would be: $53.5 \text{ SiO}_2 \times 0.8 + 36.3 \text{ PbO} \times 3.0 + 10.0 \text{ K}_2\text{O} \times 8.5 + 0.3 \text{ Ag} \times 4.0 = \text{total}; 237.1$. The expansion factor of the flash glass is about 9 units too high for the base glass. About 1% less K_2O must be used in the flash glass and in place of it 1% SiO_2 must be added. The factors then for base and flash glasses will be approximately the same. A similar additional example is given with calculations dealing with a white milk glass flashed on a clear base glass. Sometimes substitutions of one oxide for another must be made in adjusting the expansion numbers; for example, barium for lead, soda for potash, etc.

C. H. KERR.

Blue enamels for glass. *Schnurpfeil's Review for Glass Works*, **4**, No. 42, 667 (1920).—(1) Turquoise blue: lead 100, borax 60, quartz 100, tin oxide 20, copper oxide 14; (2) dark: blue lead 85, borax 10, quartz 37, cobalt oxide 1.

R. J. MONTGOMERY

Opal for glass shades. *Schnurpfeil's Review for Glass Works*, **4**, No. 42, 667 (1920).—Sand 100, soda ash 28, nitrate of soda 6, lead 6, cryolite 3, feldspar 30, fluorspar 30, arsenic 1.

R. J. MONTGOMERY.

French basalt for making champagne bottles. *Schnurpfeil's Review for Glass Works*, **4**, No. 42, 667 (1920).—An analysis gave silica 46.17, alumina 14.96, iron 13.78, lime 9.93, magnesia 6.26, potash 3.48, soda 2.65. Total 97.23.

R. J. MONTGOMERY.

Phonolite used in green bottle glass. *Schnurpfeil's Review for Glass Works*, 4, No. 42, 667 (1920).—Phonolite is an excellent ingredient as this mineral contains alumina and magnesia as well as iron oxide. An analysis of phonolite is given as silica 54.66, alumina 23.38, lime 3.26. Soda 7.00, iron, 4.50 magnesia 1.21, potash 4.29. Two suggested batches are—Batch No. 1 (with salt cake), yellow sand 1000, phonolite 1200, lime 450, salt cake 400, coal 20, cullet 300. Batch No. 2 (with soda ash), yellow sand 1000, phonolite 1200, lime 450, soda ash 300–310, cullet 300.

R. J. MONTGOMERY.

Composition of acid paste. *Schnurpfeil's Review for Glass Works*, 4, No. 42, 669 (1920).—This acid paste is recommended for fine designs. Powdered sulphate of potash 11, potassium fluoride 20, hydrochloric acid 11, hydrofluoric acid 3, wheaten flour 22.

R. J. MONTGOMERY.

On a new type of gas-fired furnace. MORRIS W. TRAVERS. *J. Soc. Glass Tech.*, 4, 205–25 (1920).—The Dennis Simplex Furnace is described in detail. The older furnace consisted of a gas-fired furnace of a Continental pattern with 2 producers built into the center of it and flanked by recuperators. The gas from the producers rose through a central eye, meeting the hot secondary air from the recuperators at a point a little beneath the sieve. The 8 pots stood in a circle around the eye, the products of combustion passing between the pots, through openings in the pillars supporting the crown and then down into flues leading to the recuperators. Following the collapse of one of the flues and the filling of one of the recuperators by glass, the furnace was rebuilt and the producers were replaced by Frisbie under-feed grate. The resulting efficiency was remarkable. Tests showed above 1 ton and usually from 1½ to 2 tons of metal per ton of fuel, the glass being a soda-lead glass for electric lamp bulbs. The glass contained 33% lead oxide. The total heat required to melt 1 kg. of glass from the batch is as follows:

| | | |
|---|---|----------|
| 1 | Sum of sp. heats of SiO ₂ , PbO and Na ₂ O, as glass..... | —272.0 K |
| 2 | Latent heat of fusion of SiO ₂ | — 49.0 K |
| 3 | The heat of reaction: | |
| | (a) Na ₂ O (solid) + SiO ₂ = Na ₂ SiO ₃ | + 74.5 K |
| | (b) Pb ₂ O (solid) + SiO ₂ = PbSiO ₃ | + 12.2 K |
| 4 | The heat of reaction: | |
| | (a) Na ₂ CO ₃ = Na ₂ O + CO ₂ | — 87.4 K |
| | (b) 4NaNO ₃ = 2Na ₂ O + 5O ₂ + 2N ₂ | — 87.4 K |
| | (c) 2PbO ₂ = 2PbO + O ₂ | |
| 5 | Thermal capacity of gases liberated at or below 1000° C.. | — 21.6 K |
| | Total..... | —343.3 K |

The heat required to melt 1 kg. of this cullet and raise its temp. to 1300° C. is —274 K (greater calories). Therefore, if we assume the usual mixture of

half batch and half cullet, the theoretical amount of heat required is $-1/2$ (343 + 274) or approximately 300 K. If each pot carries 600 kg. the heat required per melt is $8 \times 600 \times -300 = -1,440,000$ K. The additional heat required in fining is discussed, also the furnace losses. C. H. KERR.

The density of soda-magnesia glasses. S. ENGLISH AND W. E. S. TURNER. *J. Soc. Glass Tech.*, 4, 153-7 (1920); cf. *C. A.* 14, 2538 (1920).—Samples must be well annealed to give reliable and concordant results. The better the annealing the higher the density will be. The relation between magnesia content and density is shown below:

| Glass No. | % MgO | Density at 20° | Glass No. | % MgO | Density at 20° |
|-----------|-------|----------------|-----------|-------|----------------|
| 1 | 0.0 | 2.4353 | 329 | 5.09 | 2.4149 |
| 24 | 1.10 | 2.4323 | 330 | 6.10 | 2.4102 |
| 25 | 1.85 | 2.4300 | 331 | 6.87 | 2.4055 |
| 26 | 2.49 | 2.4273 | 332 | 7.46 | 2.4032 |
| 27 | 3.47 | 2.4239 | 389 | 8.45 | 2.3967 |
| 28 | 4.20 | 2.4207 | 390 | 9.30 | 2.3947 |

Magnesia lowers density while lime raises density. It was found that the old Winkelmann and Schott factors for calculating density were in error and new factors were deduced. The best factors on these glasses were the following: SiO_2 , 2.20; Na_2O , 3.47; MgO , 3.38. The composition and density, observed and calculated are shown in the table.

COMPOSITION

| Glass No. | SiO_2 | Na_2O | MgO | Obs. Density | Calc. Density |
|-----------|----------------|-----------------------|--------------|--------------|---------------|
| 24 | 74.07 | 24.23 | 1.10 | 2.4223 | 2.440 |
| 25 | 74.35 | 23.46 | 1.85 | 2.4300 | 2.433 |
| 26 | 75.00 | 22.12 | 2.49 | 2.4273 | 2.427 |
| 27 | 75.16 | 20.69 | 3.47 | 2.4239 | 2.431 |
| 28 | 75.19 | 19.83 | 4.20 | 2.4207 | 2.431 |
| 329 | 76.30 | 18.26 | 5.09 | 2.4149 | 2.413 |
| 330 | 77.09 | 16.05 | 6.10 | 2.4102 | 2.412 |
| 331 | 76.68 | 15.77 | 6.87 | 2.4055 | 2.414 |
| 332 | 76.86 | 14.55 | 7.46 | 2.4032 | 2.419 |
| 389 | 77.77 | 13.40 | 8.46 | 2.3967 | 2.397 |
| 390 | 78.28 | 11.76 | 9.30 | 2.3947 | 2.397 |

Further work is being done on these factors to make them fit a wide range of glasses. C. H. KERR.

Composition of glass insulators. *Schnurpfel's Review for Glass Works*, 4, No. 42, 669 (1920).—Glass to be made in a tank furnace (1) white insulators. Sand 1000, soda ash 300, feldspar 350, fluorspar 350, clay powder 100, eryolite 25. (2) Black insulators. Yellow sand 1000, soda ash 330, lime 200, fluorspar 60, graphite 160.

R. J. MONTGOMERY.

Glass for lamp chimneys. *Schnurpfel's Review for Glass Works*, 4, No. 42, 669 (1920).—A glass without potash is as follows: sand 100, soda ash 32, lime 16, lead 6, borax 2, alumina 1, saltpeter 2, arsenic 1, manganese 4 oz.

R. J. MONTGOMERY.

The development of optical glasses during the war. C. J. PEDDLE. *J. Soc. Glass Tech.*, 4, 225-38 (1920).—Before the war 90% of England's glass was imported and 60% came from Germany. Only one firm, Chance Bros. was then producing it in England. This paper refers to the development during the past three years at the Derby Works of Wood Bros. Glass Co., Ltd., of Barnsley. The present quality of English optical glass is up to pre-war standards, in some ways superior. It is intended that all scientific knowledge gained in the development will be published. The greatest difficulty in optical glass production is the pot. Another difficulty is in having to produce glasses of prescribed optical characteristics to fit previously made calculations, whereas the Germans made certain glasses and opticians fitted those glasses into their optical systems.

C. H. KERR.

The manufacture of mother-of-pearl glass. O. SCHWARZBACH. *Sprechsaal*, 53, 251-2 (1920).—While the manufacture is fairly old, most of the important developments have come within the past 10 years. The usual basis of the mother-of-pearl glass is a mixture about as follows: sand, 100; potash, 45; red lead, 52; bone ash, 8 parts by weight. Often instead of the lead oxide there are used 4 parts potassium nitrate, and 8-9 parts calcined guano which give an intense cloudiness on cooling and heating repeatedly. To make an antique mother-of-pearl, like the old Venetian ware a little manganese is added. A typical batch for the base glass would be: sand, 145; red lead, 20; lime, 18; soda ash, 40; manganese, 0.5 parts. In Bohemia a base glass is used of the following mix: sand, 40; red lead, 40; potassium carbonate, 10; potassium chloride, 0.25; sodium nitrate, 5; arsenic, 0.5; calcium phosphate, 1.25. The opacifying materials here are the potassium chloride and the calcium phosphate. In America, the opal or opalescent glass is made from a batch about as follows: sand, 100; soda ash, 35; fluorspar, 22; feldspar, 40; red lead, 5; sodium nitrate, 5. Or with the same proportions of sand and soda ash, 40 of fluorspar and 20 of barium carbonate are used. The German opal glass is made about as follows: sand, 68; potash, 21; soda ash, 5; red lead, 5; saltpeter, 1; borax, 1; calcium carbonate, 4; bone ash, 6-10. The best opacifiers, ones which will burn out least, are cryolite and bone ash, especially with the addition of a little zinc white.

C. H. KERR.

American glass practice. New book by HARRY BASTOW. Published by the Glassworker, Box 555, Pittsburgh, Pa. This book contains chapters on glass-making, managerial problems, materials, annealing, melting, etc.

R. J. MONTGOMERY

Old bead-making art having revival now. *The Glassworker*, 39, No. 50, 22 (1920).—The history of bead making is traced from ancient days to modern

times. The early Egyptian beads were of exquisite designs and finished in globes, ovals, cylinders, long and short bugles and cubes with plain or grooved surfaces. They are composed chiefly of glass and baked clays. Types differed somewhat with location and time and include those of Assyria, Rome, Egypt, Phoenicia and Baltic Regions. Early Anglo-Saxon beads were composed generally of light colored clay, sometimes glazed although glass was also used. In the middle ages the making of glass beads was almost entirely confined to Venice. In 1764 no less than 600 varieties were produced. In modern beadwork earthenware is extensively used, both glazed and unglazed. By compounding two or more different colored clays with glazes, intricate designs can be carried out.

R. J. MONTGOMERY.

Venetian glass beads. *Schnurpfeil's Review for Glass Works*, 4, No. 42, 465 (1920).—The glass bead industry may be divided into four branches, (1) ordinary beads or "conterie," (2) lamp beads, (3) black beads for mosaics and (4) goldstone. The divisions given are based upon the method of manufacture, a brief description being given of each. All the work is done by hand. The average annual production of beads of all kinds in Venetia is estimated at 4,750 metric tons.

R. J. MONTGOMERY.

Is bottom heat necessary for satisfactory glass melting? ANON. *Sprechsaal*, 53, 277-8 (1920).—While it is admittedly possible to secure good melting results by the use of top heat only, a careful investigation of comparative results shows that bottom heat also is desirable. By bottom heat is meant heat underneath the pot but in the superstructure of the furnace, not that from the regenerator chambers, etc.

C. H. KERR.

The progress of the melting process in shallow glass pots. JOHANN BALDERMANN. *Sprechsaal*, 53, 205-6 (1920).—In glass plants it is quite common for the workman to lay the blame for failure to accomplish proper melting upon the lack of bottom heat. A wide experience has shown that top heat is of greater importance and is more economical in the proper melting of the batch and in the fining operations. The progress of the typical melting operation is described. When the first fill is put on, there is a layer of molten cullet in the bottom of the pot. The raw batch sinks to the bottom and molten glass, rich in alkali, is formed on top. Gradually the batch reacts and becomes dissolved and in about 3½ hrs. there is only a small flat cone of raw batch. By the 4th hour, boil has started and the remaining small amount of raw batch has risen to the surface. The second fill is put on at 4½ hrs. and it floats and melts. At 7 hrs. the second fill is about gone and at about 7½ hrs. violent boil sets in. The boiling continues for about 1½ to 2½ hrs. so that at about 10 hrs. the metal is plain. At about 11-12 hrs. the fining is finished. The typical pot used in the illustrations is 42" diam. with 6" thick bottom and 17" deep to the inside of the bottom.

C. H. KERR.

The use of phonolite in glass manufacture. ANON. *Sprechsaal*, 53, 227-8 (1920).—The possible use of phonolite in glass mixtures has been referred to for about 10 years. With the present scarcity and high price of salt cake and soda ash there is increased reason for considering its use. The phonolite offered by firm Rhenania in Aachen shows the following composition: Al_2O_3 , 24.0; Fe_2O_3 , 2.3; CaO , 1.2; MgO , 0.3; K_2O , 9.5; Na_2O , 8.1; SiO_2 , 50.3; CO_2 , 0.2; P_2O_5 , 0.1; H_2O , 3.2%. The use of 100 lbs. of this phonolite is about equivalent to 50 lbs. sand and 36 salt cake, or 50 sand and 27 soda ash. The alumina is considered as replacing silica in the glass in equivalent proportions so that 24 alumina about replaces 14 silica. The alumina is frequently a beneficial addition to the batch, especially in bottle glasses. The following formulas for half-dark bottle glasses show how phonolite may be used:

| | Hand working | | Machine glass | |
|------------------|-------------------|----------------|-------------------|----------------|
| | Without phonolite | With phonolite | Without phonolite | With phonolite |
| Sand..... | 1000 | 850 | 870 | 700 |
| Salt cake..... | 222 | 110 | 260 | 280 |
| Coal..... | 7 | 5 | 10 | 14 |
| Soda ash..... | .. | ... | 80 | ... |
| Phonolite..... | .. | 300 | ... | 280 |
| Yellow marl..... | 510 | 510 | 400 | 380 |
| White marl..... | 270 | 270 | 300 | 380 |
| Manganese..... | 10 | 10 | 35 | 22 |
| Slag..... | 60 | ... | 50 | ... |

The marl analyses follow:

| | Yellow marl | White marl |
|-------------------------------|-------------|------------|
| Ignition loss..... | 3.69 | 10.72 |
| SiO_2 | 15.23 | 16.18 |
| Al_2O_3 | 5.97 | 4.31 |
| CaCO_3 | 44.72 | 63.89 |
| MgCO_3 | 25.47 | 0.78 |
| Fe_2O_3 | 2.18 | 1.85 |

C. H. KERR.

Fuels and gas producers in the glass industry. ANON. *Glasindustrie*, 31, 121-2, 129-30 (1920).—A little over half of the cost of producing finished molten glass lies in the fuel cost—hence its great importance. In good tank practice the fuel cost is about one-third. For the production of 1 kg. of finished molten glass under the various conditions the fuel consumption averages as follows: direct furnace firing, 3 kg.; producer gas firing, 2 kg.; half-gas producer firing (Boetius furnace), 2 kg.; continuous tank, 0.8 kg. Data are given regarding the calorific value and comparative consumption of various kinds of coal, peat and wood.

C. H. KERR.

Composition of glass for light green bottles. *Schnurpfeil's Review for Glass Works*, 4, No. 41, 647 (1920).—Sand 1000, sulphate of soda 325, chalk 465, coal 27, manganese 1.
R. J. MONTGOMERY.

Composition of glass for thermos bottles. *Schnurpfeil's Review for Glass Works*, 4, No. 41, 647 (1920).—Sand 100, soda ash 36, lime 20, alumina 6, borax 4, cullet 20. This glass is easily annealed.
R. J. MONTGOMERY.

Salt peter. *Schnurpfeil's Review for Glass Works*, 4, No. 41, 643 (1920).—Used as NaNO_3 or KNO_3 softens the glass and causes quicker melting but its chief value is as a decolorizing and oxidizing agent. Nitrate can be replaced by arsenic to oxidize and decolorize while an increase in the carbonates of Na and K will give the desired softness. Alkali nitrates are not necessary in a glass.
R. J. MONTGOMERY.

Composition of glass for best quality table ware. *Schnurpfeil's Review for Glass Works*, 4, No. 41, 647 (1920).—Sand 100 lbs. potash 30 lbs., lead 70 lbs., nitrate of potash 7 lbs. arsenic 8 oz., manganese 3 oz.
R. J. MONTGOMERY.

Composition of opal glass. *Schnurpfeil's Review for Glass Works*, 4, No. 41, 649 (1920).—No. 1. Sand 100, soda ash 29, feldspar 30, fluorspar 20, alumina 5, tin oxide 1. No. 2. Sand 100, soda ash 28, barytes 7, feldspar 20, fluorspar 15, cryolite 7, zinc oxide 3.
R. J. MONTGOMERY.

Composition of glass for pressed tumblers. *Schnurpfeil's Review for Glass Works*, 4, No. 41, 649 (1920).—Sand 100, soda ash, 33, barytes 3, lime 16, salt peter 2, manganese 0.15.
R. J. MONTGOMERY.

The measurement of internal forces by means of optical methods. H. SCHULZ. *Sprechsaal*, 53, 3-4, 1/1; *Chem. Zbltt.*, N., 16, 1920, Bd. 11, 21 Apr.—H. experimented with previously used apparatus for determining the stresses present in elastic bodies with the thought of applying same to technical problems especially in the glass industry.
WM. M. CLARK.

On the influence of strain on the properties of optical glass. G. BERNDT. *Ztschr. f. Instrumentkunde*, 40, 20-27, Jan.; *Chem. Zbltt.* N., 20, 1920, Bd. 11, 19 May.—B. investigated the effect of rapid and slow cooling on the production of tension and compression strains in glass bodies and the effect of these strains on the tensile strength, modulus of elasticity, refractive index and expansion coefficient of the glass. Also the amount of strain was calculated and compared with observed values and found to agree closely in a number of instances. It was demonstrated that glass follows Hooke's law up to the point of fracture. The early part of the article deals with the tensile strength of plate glass.
WM. M. CLARK.

On the standardization of glass apparatus. FRITZ FRIEDRICHS. *Z. angew. Chem.*, **33**, 56, 2/3 (20/1); *Chem. Zbltt. N.*, **20**, 1920, Bd. 11, 19 May.—Deals with the fundamental laws which must be followed on the standardization of form, mass and material of glass apparatus. WM. M. CLARK.

Corrosion of glass flasks used in the laboratory. DUBRISAY. *Bull. soc. chim.* **27**, 409-11 (1920).—The surface tension at the surface of sepn. between water and an organic solution of a fatty acid such as oleic or stearic acid in benzene is greatly decreased by the presence of traces of alkali in the aqueous phase. This decrease has been used in studying the corrosion of glass by water with liberation of NaOH or KOH. The 10% oleic acid solution was allowed to run slowly from a pipet into the water to be tested, and the number of drops corresponding to 1 cc. counted. The larger this number the higher the alkali content. In determining attack by alkali a definite amount of NaOH solution was run into the flask and evaporated almost to dryness. An equivalent amt. of acid was added, and the excess alkali liberated from the glass determined as above. Tested in this way a glass flask lost in boiling water 0.475 mg. per hour per cm.². French chemical glass was about as resistant to water as foreign glass, while Jena glass was more resistant to alkali. C. A.

The discoloration produced by lead, antimony and arsenic in lampworked glass tubing. F. W. HODKIN AND W. E. S. TURNER. *J. Soc. Glass Tech.*, **4**, 158-61 (1920).—Fifty experimental melts were made using a good lampworking glass throughout, and adding graduated quantities of lead oxide, arsenious oxide, antimony oxide, with and without nitre, also with and without manganese as a decolorizer. Both arsenic and antimony caused discoloration when the tubing was worked in the flame, far more than with lead oxide. Amounts as small as 0.02 to 0.05% will cause discoloration. With lead oxide about 0.6% is required to cause discoloration. The results seem independent of the presence or absence of nitre or manganese. C. H. KERR.

Annealing temperature of glass. MASAMICHI SO. *Proc. Phys.-Math. Soc. Japan*, [3] **2**, 113-6 (1920).—This investigation shows that the relation between the temp. and the time required for the annealing of borosilicate glass, soda glass, lead glass and soda-lead glass is a logarithmic one expressed by the equation $H = aT^{-n}$, where H = the annealing time, T the annealing temp., and a and n consts. depending upon the compn. of the glass and the degree of its internal strain. C. A.

Internal welding in the working of glass. HENRI VIGREUX. *Ann. chim. anal. chim. appl.*, **2**, 145-7 (1920).—With the ordinary methods of internal welding of glass, some breakage always occurs even when the best care is exercised. A method is described which overcomes this by using a soft glass outside and a hard glass on the interior. This method can not be used, however, for a double internal weld and it offers another difficulty in that it is not practicable to join laterally or end to end, two different glasses. C. A.

PATENTS

Attaching caps to glass bulbs, etc. BRITISH THOMSON-HOUSTON CO. Brit. 141,182, Mar. 29, 1919. Caps are attached to elec. incandescent lamps or other glass bulbs by a cement which softens at a moderate temp., *e. g.*, 200°, and hardens at a higher temp., *e. g.*, 300°; the heating takes place during exhaustion of the bulb. A suitable cement consists of 1 part by wt. of bakelite, 1 to 2 parts resin, and 8-10 parts marble dust as a filler to reduce shrinkage, with a solvent such as wood alc. The operation may be carried on in an oven. A suitable construction is specified. C. A.

Apparatus for gathering molten glass. JOSEPH B. GRAHAM. U. S. 1,353,953, Sept. 28, 1920. The machine with means for establishing a flow of glass, of a two-part receptacle to temporarily support the glass as it accumulates therein to form a gather, a cut-off device forming a closure for the bottom of the receptacle, a pneumatic motor to actuate the receptacle for discharging the gather; a pneumatic motor for operating the cut-off device, separate pneumatic timing devices for the motors, valves controlling the supply of air pressure for setting the timing devices and means to cause the actuation of the controlling valves in timed relation.

Means for and method of flowing glass. JOSEPH B. GRAHAM. U. S. 1,353,907, Sept. 28, 1920. This apparatus has a receptacle for supporting a mass of molten glass, comprising lateral and bottom supporting surfaces and way to withdraw the bottom surface and leave the glass supported by the lateral surface the latter formed to temporarily sustain the weight of the glass, and means to withdraw the lateral surfaces and thereby permit the glass to drop by gravity.

Glass drawing machine. FELIX L. GOFFAUX. U. S. 1,354,391, Sept. 28, 1920. A device described comprising an elevator, a bait of rectangular form carried by the elevator, a vertically movable supporting member and rollers carried by the member for engaging the glass tube being formed.

Glass-retaining device for containers. JAMES RIZZUTO. U. S. 1,352,531, Sept. 14, 1920. A combination with a container having an opening in one of its walls, a bar positioned transversely of the inner surface of the wall having the opening, a glass insert positioned between the bar and the wall having the opening, to cover the opening, an element pivoted on the bar and having a portion overlying one edge of the bar and one edge of the glass insert, a U-shaped clamp carried by the end of the element adapted to straddle the bar and the glass, one arm of the clamp being bent upon itself and the end of the bent portion terminating in a lug to be engaged by the finger for disengaging the clamp, the arm where it is bent having a lateral lug overlying the lower edge of the bar, thereby cooperating with the arch of the clamp to retain the glass insert in position in case the container is inverted.

Window-glass-flattening oven. HARRY E. DE VAUGHN. U. S. 1,352,881, Sept. 14, 1920. A shove pan track formed of tubular rails closed at their ends, water-distributing tubes extended longitudinally into the rails through one closed end thereof, each water tube having a discharge end located contiguous to the other fluid supply pipe connecting the supply ends of the tubes, and a transversely disposed rigid discharge pipe lying contiguous to the supply pipe and connecting the rails, the supply and discharge pipes coöperating to brace the rails.

Machine for finishing blown-glass articles. JAMES BAILEY. U. S. 1,352,396, Sept. 7, 1920. This device has a bulb tray, and automatic resilient means to rock the tray, a member having a stripping notch above the tray, and a latch moved by an insertion of the blow-iron in the stripping action to lock the tray against rocking, also a transfer mechanism adapted to lift a bulb out of a chuck, of a resiliently supported pad adapted to raise the bulb into gripping engagement with the transfer mechanism.

Drop-feeding device for glass machines. ALEXANDER L. SCHRAM. U. S. 1,353,276, Sept. 21, 1920. This machine with partible cup shaped gathering devices, one of which is provided with a glass severing edge, a knife, a support for the knife permitting vertical play thereof when moved and an adjustable weight acting on the knife to cause its cutting edge to bear against the cutting edge of one of the gathering devices.

C. M. SAEGER, JR.

Whiteware and Porcelain

A study of the hardness of glazes. ANON. *Tech. News, Bull. Bur. of Standards*, No. 42, p. 11 (1920).—An attempt is being made to differentiate the different glazes applied to clay products according to their hardness by tests similar to the Brinell test commonly used for metals. The hardened steel sphere used in the Brinell machine is replaced in this case by a conical steel point, the penetration of which into the glaze under high pressure is an index of the hardness of the material. This penetration is measured by means of a micrometer microscope. The pressures employed for forcing the point into the glaze are quite high and have been as great as several hundred thousand pounds per square inch. Although the test has not yet been brought to a satisfactory status, it has differentiated between the several types of enamels and glazes examined, thus enamels are punctured under fairly low pressures while high-fire porcelain glazes are exceedingly resistant, while white ware glazes occupy an intermediate position.

A. E. MALCOLM.

High-fire porcelain glazes. ANON. *Tech. News, Bull. Bur. of Standards*, No. 42, p. 11 (1920).—It has been found that the range of compositions suitable for high-fire porcelain glazes increases rapidly with the temperature. The glazes of low silica content have been found to over-fire at the temperatures corresponding to Cone 12. The limits of suitable glazes for tem-

peratures up to Cone 16 have been established quite definitely. The final report is now being edited and revised. A. E. MALCOLM.

Enamels

Composition of white cast iron enamels. *Schnurpfel's Review for Glass Works*, 4 No. 41, 647 (1920).—No. 1. Borax 22.0, feldspar 46.0, carbonate of soda 12.0, saltpeter 0.75, tin oxide 15.5, fluorspar 1.0. No. 2. Borax 19.0, feldspar 32.0, soda 6.5, saltpeter 2.5, cryolite 1.5, tin oxide 8.5, fluorspar 3.0, zinc oxide 2.5, bone ash 2.0. R. J. MONTGOMERY.

Brick and Tile

The strength of perforated bricks. PROF. TETMAIER. *Brit. Clayworker*, 29, 22 (1920).—The following data on perforated brick is given:

| Solid bricks, Tons per sq. ft. | Perforated Tons per sq. ft. | No. of holes. | Diam. of holes, in. |
|-----------------------------------|--------------------------------|---------------|------------------------|
| 276 | 411 | 14 | 0.6 |
| 161 | 178 | 12 | .7 |
| 147 | 149 | 12 | 1.0 |
| 130 | 154 | 10 | 0.7 |
| 202 | 238 | 14 | .8 |
| 329 | 383 | 14 | .8 |

Perforated brick are in every case stronger than solid brick. Similar results were obtained in Dr. Segers's laboratory in which a solid brick had a crushing strength of 315 tons per sq. ft. and a perforated brick of the same material had a crushing strength of 504 tons per sq. ft. These results seem to show that perforated brick are both lighter and stronger than solid brick which may be of great importance in the building industry.

H. G. SCHURECHT.

Tile fungus. J. SCORR. *Brit. Clayworker*, 29, 138-40 (1920).—Roofing tile are often porous and in this condition may become disintegrated through fungus growth. A type of fungus known as *mucor racemosus* is especially destructive. Rain and dust settle in the pores providing a foundation for the spores. As these spores grow they form a network through the pores resembling a spider web. The fungus may mature in a few days when it sends thread-like stalks up into the air on which spore balls appear which are capable of starting new plants. The fungus obtains its food partly from the dust and partly from the tile. All threads are hollow and filled up with traveling sap. Their points yield ferments which enables them to soften and split off small particles. In doing this the available mineral matter required is drawn from the tile, leaving it more susceptible to the destructive action of freezing. Lichen which often covers roofing tile is not destructive as it derives its nourishment from the air.

H. G. SCHURECHT.

PATENTS

Brick. FRANK W. BUTTERWORTH. U. S. 1,353,515, Sept. 21, 1920. A brick or the like having an entire surface provided with closely spaced, short, and narrow indentations disposed in substantially parallel lines and all extending in one and the same direction, whereby the appearance of the surface is the same in whatever position the brick may be laid.

Method and apparatus for cutting bricks or blocks from natural deposits. EDWARD B. STARR AND HOWARD E. MARSH. U. S. 1,353,188, Sept. 21, 1920. This apparatus for cutting bricks or blocks from banks, comprising track means with a truck adapted to travel thereon, cutting devices movably mounted to move transversely to the track.

Process for handling clay products. JONATHAN P. B. FISKE. U. S. 1,352,947, Sept. 14, 1920. In manufacturing hollow clay articles into a vertical alinement, lowering a pair of clamping devices adapted to be electrically energized through adjacent vertical air spaces in the column of clay articles, the pair of electrical clamping devices being positioned on each side of an inner web in the clay articles, then supplying electrical energy to the clamping devices, whereby the pair of devices will clamp automatically on opposite sides of the inner web of each article in the column and then lifting the clamping devices and the column of articles, while the clamps are energized, deenergizing the magnets and releasing the articles.

Brick machinery. FRANK B. LAMBERT. U. S. 1,353,917, Sept. 28, 1920. A dry press, a sharply tapered screw having a single thread of relatively large pitch, with mechanical means for rotating the screw, a screw casing having an inner surface closely approximating the outer edges of the screw, the casing having an inner surface closely approximating the outer edges of the screw, the casing having covered its inner tapered surface substantially by a plurality of shallow screw threads alternated with grooves of substantially the same width as the threads, the side faces of the threads which receive the clay being inclined to the axis of the screw and adapted to direct the clay toward the axis of the casing as the same is forced forward by the screw.

Brick-machine. JAMES CARREL DOBBINS. U. S. 1,352,056, Sept. 7, 1920. A brick machine comprising a main frame including a horizontally disposed upper portion having a forward mold board support, an upright slotted wall along the rear of the support forming the rear mold wall, a front mold wall having a pivoted connection with the main frame and shiftable with respect thereto into and out of position opposing the rear mold wall, a series of lengthwise shiftable partitions rigidly connected to one another and the forward ends of which are movably disposed in the slots of the rear mold

wall, a mold board or pallet removably disposed between the front and rear mold walls, rigid connections between the partitions, and manually actuated means for shifting the partitions forwardly and rearwardly on the main frame.

C. M. SAEGER, JR.

Cement and Lime

The properties of portland cement, iron portland cement, blast furnace cement and hydraulic binders. H. BURCHARTZ. *Mitteilungen aus dem Materialprüfungsamt zur Berlin-Lichter-felde West*, 1 and 2, 85-109 (1920); *Tonind.-Ztg.* 44, 753-4 (1920).—The bulk sp. gr. of portland cement which had been poured R1 varied between 1.05 and 1.25 kgs./l. and averaged 1.16 kgs./l. That of Portland cement which had been shaken Rr varied considerably and averaged 1.95 kgs./l. The sp. gr. of air dried cement sl, lay in 60 per cent of the cases between 3.05 and 3.15. The rest of the values were very close to 3.20. The sp. gr. of the ignited cements were between 3.20 and 3.30 in 86 per cent of the cases. The 3 cements showed little difference in their sp. gr. while the hydraulic binder had a lower sp. gr. than the cements. The per cent loss on ignition of the Portland cements were between 1 and 3 per cent in 60 per cent of the cases, 4 per cent were under 1 per cent and 36 per cent were over 3 per cent. Cements with a high loss on ignition had a low sp. gr. For ex. the av. weights of R1 = 1.160 kgs./l., Rr = 1.190 kgs./l. and sl = 3.200. For cements with more than 4 per cent ignition loss these values become R1 = 1.080 kg./l., Rr = 1.120 kg./l. and sl = 3.040. During storage the loss on ignition increases and sp. gr. decreases. The water required for Portland cement varies in 70 per cent of the cases between 23 and 27 per cent with an av. of 25.7 per cent. The amts. required for iron Portland cement and blast furnace cement were very similar to that required for Portland cement but that required for hydraulic binders is considerably more owing to the free lime. The time of setting of the Portland cements varied between 8-12 hrs. Only 2 of the 153 Portland cements tested were quick setting, i. e., less than 2 hrs. All others were slow setting, 14 which first set after 12 hrs. The initial set of Portland cements varied in 84 per cent of the cases between 2-6 hrs. 84 per cent of the Portland cements had 0-1 per cent on a 900 mesh sieve, 7 per cent had 1-2 per cent, and 9 per cent more than 2 per cent. The iron Portland cement had 0.3 per cent, the blast furnace cement had 0.6 per cent and the hydraulic binder had 2.2 per cent. The Portland cement had in 62 per cent of the cases a residue of 10-20 per cent on a 5000 mesh sieve, 21 per cent had less than 10 per cent and 18 per cent had more than 20 per cent and 11 per cent had between 20 and 25 per cent. Hydraulic binder had 11.4 per cent and iron Portland cement had 7.4 per cent. The tensile strengths after 7 days of 153 cements were above the required 12 kgs./sq. cm. In 66 per cent of the cases they lay between 15-25 kgs./sq. cm. The 28 day trials in 53 per cent of the cases were between 25-30 kgs./sq. cm., 11 per cent were less than 25 kgs./sq. cm. and 36 per cent were more than 30 kgs./sq. cm. The 7 days compression strength tests varied considerably. 8 cements did not meet the specifications, 55 per cent lay be-

tween 250–350 kgs./sq. cm., 33 per cent were less than 200 kgs./sq. cm. and 12 per cent were more than 350 kgs./sq. cm. The 28 day trials varied still more. 4 cements of the 117 tested did not meet the specifications after 28 days in water, and 6 of 149 cements did not meet the specifications after 28 days in air. 38 per cent of the cements stored in water for 28 days and 65 per cent of the cements stored in air for 28 days had a compression strength of more than 350 kgs./sq. cm. 46 per cent of the cements stored in water had a compression strength of 450–550 kgs./sq. cm. 1 cement reached the value of 544 kgs./sq. cm. With combined storage for 28 days, 72 per cent of the cements had a strength of 300–450 kgs./sq. cm., 15 per cent had strengths under 300 kgs./sq. cm., 13 per cent were above 450 kgs./sq. cm. and 5 per cent were between 500 and 700 kgs./sq. cm. 1 reached a compression strength of 667 kgs./sq. cm. The av. strengths were 60 per cent greater than for water storage and 52 per cent greater than for air storage. The relation of tensile strength to pressure is very uniform in 70 per cent of the cements, the ratio being between 8–12. With 43 per cent of the cements the tensile strength of a standard mix increased 20–30 per cent in 7–28 days. In 26 per cent of the cases its increase was less than 20 per cent, in 37 per cent of the cases it was more than 30 per cent and in 5 per cent it was 50–60 per cent. The av. increase was about 27 per cent. The av. increase in compression strength was 51 per cent. The chem. composition of 19 Portland cements, 8 iron Portland cements, and 6 blast furnace cements were obtained. The Portland cements as a rule were normal. Only one cement had an unusual low lime content (58.22 per cent) and another an unusual high silicic acid content (27.66 per cent). By no Portland cement was the magnesia content above normal, *i. e.*, 5 per cent. The av. was 3.69 per cent. One Portland cement had more than 2.5 per cent SO_3 , namely 3.69 per cent. The others all had less than 2.5 per cent. The sulphur content was quite uniform for Portland cements, somewhat higher for iron Portland cement and highest for hydraulic binders. The silica content of Portland cement and hydraulic binders were about the same, a little higher for iron Portland cement and highest for blast furnace cement. The Al_2O_3 and Fe_2O_3 content varied in the same order, and the CaO content varied in the reverse order. The hydraulic mod.

$$\frac{\text{CaO}}{\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3}$$

for Portland cement was 1.7 with one exception when it was 2.48. With iron Portland cement it varied between 0.95 and 1.26. For hydraulic binders it was close to that of Portland cements. H. G. SCHURECHT.

Foam slag brick. ANON. *Brit. Clayworker* 29, 137 (1920).—During the war various attempts were made in Germany to utilize waste slags for building purposes. The foam slag differs from granulated slag in that it is introduced into water as it comes from the furnace. The steam generated blows the slag into a porous mass similar to pumice stone. Schol the inventor has given to this product the name "thermosite." Those slags containing 47–44 per

cent lime and 35-38 per cent silicic acid give the best results. This material is a better insulator than asbestos and half as good as cork. The slag is ground and screened and the fine material is mixed in a proportion of 3 to 1 with calcined lime. The lime is slaked and this product is then ground with blast furnace slag in the proportion of 85 parts slag to 15 parts lime hydrate. This final material constitutes slag cement which is used as a binder for thermosite stones. The coarser portion ($3\frac{1}{2}$ to 12 mm.) of the foam slag is then mixed with the slag cement in a proportion of 1 part cement to 6 parts of foam slag. The brick are made in 2 h. p. presses at the rate of 800-900 per hr. The brick are dried by exposure to exhaust steam at a temp. of 60-80° C. They are then left in the open for a month. The brick meas. $25 \times 12 \times 9.5$ cm. and weigh 2.2-2.7 kgs. Their compression strength is 9.6-16.5 kgs. per sq. cm. The brick do not decrease in strength after storage in water. The large size of the brick and their strength make them especially suited for building since only 227 liters of mortar are required per cu. m. of masonry as compared with 329 liters for ordinary brick.

H. G. SCHURECHT.

PATENTS

Casting slag. T. F. HOARE. Brit. 141,390, Feb. 1, 1919. Slag is cast in molds having double walls insulated by a filling of asbestos, etc., to insure even cooling or annealing. The molds may be made of Fe, slag, brass, gun-metal, etc., and may be heated prior to casting, *e. g.*, in the annealing chamber or by a small furnace. The invention is applicable to the manuf. of molded products such as paving and building blocks. A roughened appearance may be imparted to the molded products by sanding the molds, or the molds may be formed with patterns, figures, etc. Coloring materials may be applied to the molds, or to the products after removal from the molds, or may be mixed with the slag. A timber-like finish may be imparted to the products by applying bands of color to the faces of the molds. Slag direct from the blast furnace is preferably employed, but slag contg. an excess of CaO is run into a large receptacle and mixed with 10-15 per cent of SiO_2 . C. A.

ACTIVITIES OF THE SOCIETY

Important Actions of the Board of Trustees

October 19.—It was voted to authorize the formation of an Industrial Division on "Ceramic Decorative Processes," the exact title to be chosen when organization is completed at the next Annual Meeting.

October 19.—It was voted to send a delegate to the meeting of the Engineering Council in Chicago, October 21.

October 20.—It was voted to refuse the invitation of the Federated American Engineering Societies to become a member of the organization. At the same time it was voted that the President of the American Ceramic Society offer to the organization the good wishes and coöperation, where possible, of the Society.

October 20.—It was voted to repeal the resolution passed by the Board on August 4, 1919, that advertising space of $1\frac{1}{2}$ inch single column should be offered free to members of the Society, for ceramic employers seeking men and men seeking ceramic positions, inasmuch as the motion was originally passed in order to assist returned service men in obtaining positions.

New Members Received during October

Associate

Curran, Hugh, 325 East 11th Avenue, Columbus Ohio.

Eigenbrot, Edwin A., St. Louis, Mo., General Foreman, Buck's Stove and Range Company.

Engle, C. C., Toms River, N. J., Assistant Manager, Crossly Mining Company.

Gray, John R., 265 Scovel Place, Detroit, Mich., Jeffery-Dewitt Company.

Hoehl, Joseph W., 627 Wood St., Piqua, Ohio, Manager, Enameling Department, Favorite Stove and Range Company.

Jennings, Anthony J., St. Louis, Mo., Superintendent, Buck's Stove and Range Company.

McCauley, George V., Corning, N. Y., Physicist, Corning Glass Works.

Minton, C. R., 221 N. Jefferson St., Indianapolis, Ind., Engineer, U. S. Encaustic Tile Company.

Rabun, Wiley T., 124 North Santa Fe Ave., Huntington Park, Los Angeles, Cal., Foundryman, Whiting-Read Commercial Company.

Wood, O. A., 720 Walnut Ave., Fairmont, W. Va., Treasurer and Superintendent, Fairmont Window Glass Corporation.

Corporation

Alexander Hamilton Institute, Astor Place, New York City.

National Fire Proofing Company, 1126 Fulton Bldg., Pittsburgh, Pa.

Square D Company, Peru, Ind.

Joint Meeting of the Society of Glass Technology and the Glass Division

In response to an invitation that the British Society of Glass Technology meet with the American Ceramic Society in the summer of 1920, thirty-three members of that Society arrived in Boston on August 22nd. During the following four weeks they made a thousand mile inspection trip of the glass industry in the eastern half of the United States.

The itinery was as follows: Boston, one day; New York, two days; Vinceland, N. J., two days; Philadelphia, one day; Pittsburgh, ten days; Fairmont, one day; Clarksburg, one day; Charleston, one day; Columbus, one day; Toledo, two days; Muncie, one day; Corning, one day; Buffalo, one day; Niagara Falls, one day. The party then proceeded to Montreal where it sailed for home on Saturday, September 18th.

During the trip a total of forty-two glass and glass-house refractories plants were visited. The party was accompanied on the journey by Dr. E. Ward Tillotson, acting as the official representative of the American Ceramic Society. In each city visited the resident members of the Society joined with the other representatives of the glass industry and local chambers of commerce in entertaining the visitors. Numerous complimentary luncheons and dinners were served to the party during the course of the tour. The visitors appeared to be highly gratified by the welcome and entertainment they received, as is evidenced by the following, which is one of the several verses of an original song composed by one of their number and sung at a meeting in Pittsburgh:

Here's a health to your Society
From your English friends across the sea.
We've found a royal welcome here
We've had the best of all good cheer
With good cold drinks, if not much beer.

In the evening of September 2nd, a joint meeting was held in the Chamber of Commerce Auditorium in Pittsburgh for the reading of papers and for discussion, Dr. S. R. Scholes, Chairman of the Glass Division, presiding. The following papers were presented:

"Similarity between Vitreous and Aqucous Solutions," Prof. Alexander Silverman.

"Notes on the Dissociation of Ferric Oxide Dissolved in Glass and its Relation to the Color of Iron Bearing Glasses," Dr. J. C. Hostetter and H. S. Roberts.

"Provisional Specifications for Refractory Materials," Dr. W. J. Rees.

"The Nomenclature of Glass," Dr. C. J. Peddle.

"The Necessity for the Revision of the Physical State of Glass Obtained by the Workers of the Jena School," Dr. W. E. S. Turner.

On Friday, September 3rd, the Glass Division was host at a banquet at the William Penn Hotel, Pittsburgh. At this banquet Dr. S. R. Scholes presided and introduced the toastmaster, Mr. H. L. Dixon. The speakers were as follows:

Mr. John S. Herron, President of the Council of the City of Pittsburgh.

Mr. C. W. Brown, President of the Pittsburgh Plate Glass Co.

Dr. W. E. S. Turner, Secretary of the British Society of Glass Technology.

Dr. S. B. McCormick, Chancellor of the University of Pittsburgh.

Mr. Julian Osler, Birmingham, England.

The success of the long and arduous trip was due in no small measure to the courtesies extended by the railroads on which the party travelled. Special sleeping cars and special coaches were provided and officials were in attendance to insure the comfort of the party. The Society is furthermore indebted to all of the local committees for their unfailing enthusiasm and success in arranging for entertainments, and to the industrialists for their courtesies and cordial receptions to their plants.

It is felt that this joint meeting was successful beyond all expectations. International conventions are so rare as not only to make one worthy of note, but in this particular instance of societies representing the glass industry, by tradition noted for secretiveness, the spirit of cordial relationships was so marked as to promise a united and common understanding between the two societies.

The 1921 Annual Meeting

The 1921 Annual Meeting of the American Ceramic Society will be held on February 21-22-23-24, at Columbus, Ohio, where the Hotel Deshler has been engaged as headquarters. The management of this new and commodious hotel has promised to reserve the ball-room and four other rooms on the same floor, so that the general meetings of the Society and the divisional meetings will be taken care of adequately.

Details of the entertainment are in the hands of the local committee, of which Professor A. S. Watts is chairman, and it is expected that the usual Section Q, or smoker, will take place on Monday night, with the banquet on Tuesday. Those who recall these delightful events at the Philadelphia meeting will not fail to be present this year.

The trips to be taken on the last day of the meeting will be replete with interest as Columbus is situated at the very heart of the clay-working industry.

The literary program will be filled with papers of a high degree of excellence. The arrangement of the program is in charge of Mr. R. H. Minton, chairman of the Committee on Papers, and contributors should communicate with him.

Entertainment of the Ladies at the Next Convention

To the Ladies who plan to attend the coming annual Convention of the Society at Columbus, Ohio, February 21 to 24, 1921:

I desire to urge that you communicate with me at once if you are interested, whether your plans for attendance are definite or not.

I am making elaborate plans for your entertainment and am anxious to hear from you in order that a program may be provided which will meet with your approval.

Cordially yours,

MRS. ARTHUR S. WATTS,

1764 North High St., Columbus, Ohio

Necrology

JOHN RODGERS JOHNSTON.—It is with great regret that we record the death of John Rodgers Johnston, who was one of the most prominent figures in the window glass industry of this country. Mr. Johnston was born in Arcanum, Drake Co., O., on April 8, 1867. He first entered the window glass industry at Hartford City, Ind. Due to his exceptional ability he soon became the head of the Johnston Window Glass Company, which was later changed to the Johnston Glass Company.

Mr. Johnston played an important part in the formation of various glass manufacturers' organizations, notably that of the National Association of Window Glass Manufacturers some eleven years ago. He was the secretary-treasurer of that organization and one of the men who made the Association a success. He was known throughout the window glass industry of this country as a fine type of man who was always ready to give assistance to anyone that needed it. "Sec J. R." was the advice invariably given to a window glass manufacturer when he was in trouble. Mr. Johnston also took a deep interest in various civic and charitable enterprises.

Mr. Johnston was president of the Johnston Glass Co.; president of the Johnston Brokerage Co.; secretary-treasurer of the National Association of Window Glass Manufacturers; treasurer and manager of the Plate Glass Manufacturers of America, and president of the Potomac Valley Orchard Co., of Pierre, Md. He was also a member of the Union Club of Pittsburgh, the Pittsburgh Athletic Association, the Chicago Athletic Club, the Columbia Club of Indianapolis, the Pittsburgh Chamber of Commerce and various Masonic organizations.

He is survived by his wife and only child, John R. Johnston, Jr.

Amendments to the Rules of the American Ceramic Society*

(Following the text of the Rules as printed in the JOURNAL for August, 1920, Part II.)

SECTION III. PARAGRAPH 3

Associate Members shall pay no initiation fee (on and after January 1, 1921). The annual dues shall be fixed by the Board of Trustees but shall not exceed ten dollars, four dollars of which shall be a subscription to the "Journal of the American Ceramic Society."

* Effective Oct. 21, 1920.

SECTION VII. PARAGRAPH 5

The Committee on Standards shall consist of at least five members in addition to the chairman of the Standardization Committees of the several Divisions having such committees, and it shall have power to appoint subcommittees.

The divisional Standardization Committees shall be appointed in and by their respective divisions. Their function shall be the preparation of tests and specifications for the materials and products of their respective branches of the ceramic industry. Each shall be responsible to its own division, but all reports, resolutions, or recommendations that are to be printed or generally distributed shall be submitted to the Committee on Standards.

The function of the Committee on Standards shall be to prepare or have prepared tests and specifications for ceramic materials and products and to submit to the Board of Trustees written reports, resolutions, and recommendations relating thereto. The Committee may report at any regular meeting of the Society. For adoption, these reports, resolutions, and recommendations must be submitted in printed form to the members of the Society at least six months before a vote may be taken, during which time any amendments, changes, or corrections, suggested by any member may, with the approval of the Committee, be incorporated. The reports, resolutions, and recommendations as amended shall then be submitted by letter ballot to the voting members. A two-thirds vote shall be required for adoption, and the polls shall close 60 days after distribution of the ballot.

SECTION VIII. PARAGRAPH 1

Groups to be known as Divisions of the Society and to be organized from members of the Society may be authorized by the Board of Trustees for stimulating the growth and development of the Society, when such action shall seem wise and expedient. Only bona fide members of the Society are entitled to affiliate with and participate in the activities of such Divisions, but Divisions which, prior to August, 1920, have enrolled persons who are not members of the Society may retain such persons as members of the Division. A member of the society may enroll in any Division in which he is interested.

SECTION IX. PARAGRAPH 6

Any person interested in the silicate and allied industries is eligible to membership in a local Section. Membership in the parent Society is not required.

SECTION XI. ADDITION TO PARAGRAPH 3

All papers and discussions presented before Divisions and Local Sections shall become the property of the Society and their publication or other disposition shall be in the hands of the Committee on Publications.

JOURNAL OF THE AMERICAN CERAMIC SOCIETY

A monthly journal devoted to the arts and sciences related to the silicate industries.

Vol. 3

December, 1920

No. 12

EDITORIAL

THE ANNUAL MEETING

As noted in the November issue, the 1921 annual meeting of the Society will be held on February 21, 22, 23, 24, at Columbus, Ohio. The new and commodious Hotel Deshear has been engaged as headquarters.

The Committee on Papers and Programs is planning to make this meeting the most interesting and valuable, from the standpoint of ceramic technology, in the history of the Society. There will be a complete session devoted to the firing of kilns, which will cover all the different phases and types. There will also be a session devoted to the discussion of sagger problem. This is a very live topic and should prove interesting to all users of saggars. A large number of interesting papers suitable for presentation at the general sessions have been promised. In addition, arrangements are being made for the presentation of excellent programs at the meetings of each of the various Divisions.

Details of the social entertainment are in the hands of the local committee, of which Professor A. S. Watts is chairman, and it is expected that the usual Section Q, or smoker, will take place on Monday night, with the banquet on Tuesday. Those who recall these delightful events at the Philadelphia meeting will not fail to be present this year. Members are urged to bring their wives to the meeting, since special arrangements are being made to entertain a large number of ladies. The trips to be taken on the last day of the meeting will be replete with in-

terest, as Columbus is situated at the very heart of the clay-working industry.

The Collective Index

The Collective Index to the Transactions of the American Ceramic Society is ready for distribution. This will be welcome news to those who own and use the volumes, since it will increase the value of the volumes very much.

The Index has been compiled by men experienced in the kind of work involved, and careful cross-references make it possible to find subjects wherever they are mentioned or discussed. There are two parts to the book, the first a classification by authors, the second by subjects. In all there are over 7000 entries.

Bound to match the green cloth copies of the Transactions, the Index will be an important and attractive addition to both private and public libraries.

Readjustment of Dues and Fees

In former years, an Associate member was charged five dollars initiation fee and five dollars dues for each year, including the first. When he was promoted to Active membership he was charged a second initiation fee of ten dollars. Thus, the yearly average amount paid by a member in the Associate grade depended on the length of time he remained in that grade. In the case of men who were especially zealous in the work of the Society and, therefore, were quickly elevated to Active membership, it ran as high as ten, twelve and a half and even twenty-five dollars. The more dilatory members paid a much lower average fee.

On February 1st of this year the initiation fee paid by Associates upon promotion to Active membership was abolished. Beginning January 1, 1921, the initiation fee for entrance into the Associate grade will be discontinued also. At the same time, the annual dues of Associate members will be raised to seven dollars and fifty cents. The average amount received from a member will be about the same as in former years, but inequality of payment by various members will be overcome. Another advantage will be that Associate and Active members will pay the same amount, and promotion to Active membership will not be accompanied by a fee for the honor conferred.

ORIGINAL PAPERS AND DISCUSSIONS

CLAY STORAGE WITHIN THE FACTORY

BY T. W. GARVE

A raw clay storage building is not a necessity for a clay working plant, yet "the clay storage within the factory" is essential and modern plants are not built without such.

To insure continuity of operation it is necessary to have a supply of crushed and ground shale or clay on hand to bridge over breaks and delays and to keep the machinery running ahead of the bin. It is well for the superintendent, and for the men, to know in the morning that there is enough clay supply on hand within the factory to see the day through for production. Besides, any further handling and storing of clays will improve the quality of the clay by intermixing of the particles and their exposure to air.

Bins employed for such purposes are usually built overhead. This will put the storage out of the way, and allow for passage below and for the installation of feeders at the bottom for continuous and automatic feed to the grinding or pugging machinery.

For delivering raw shale or dry lumpy clay to the factory it is well to dump the contents of the car into a pocket at the bottom of which a plate feeder is operating to insure a steady uniform charge of material to the crusher (or dry pan).

If a crusher is used ahead of the dry pan it is proper to place a storage bin between them for keeping crushed material on hand. The crushed material can be fed out of such a bin by means of a reciprocating plate feeder as before or by a disc feeder. The ground material should be stored again above the pug mill with a disc feeder to permit of fine adjustments.

The amount of water required for pugging can also be regulated here close to the feeder. To insure uniformity in the water pressure, a tank can be set up above the mill and the water be piped down. Some plants have worked out a scheme of using two valves in this pipe line, one for maximum opening and complete closing and one valve ahead of it for final adjustments; or a

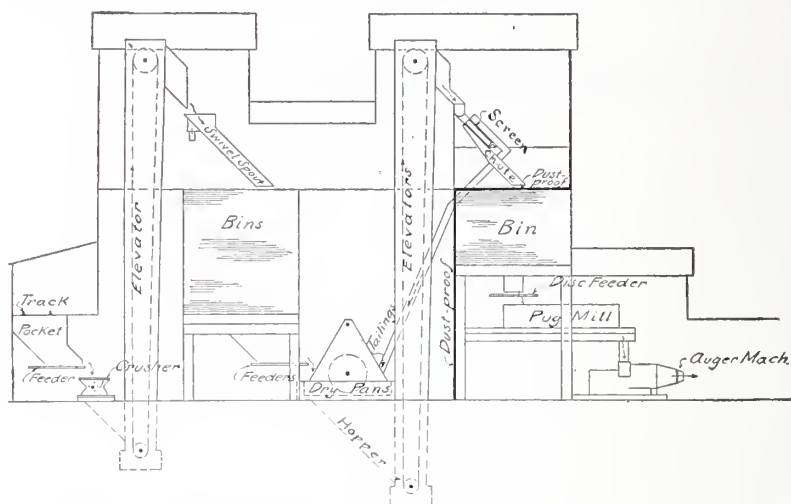


FIG. 1.—Arrangement for storing crushed shale and ground shale.

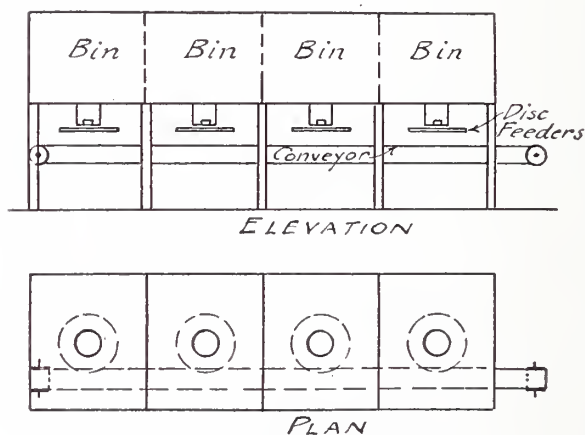


FIG. 2.—Arrangement for storing and mixing.

so-called "poidometer" can be used which weighs and regulates the amount of clay and water delivered to the pug mill.

Storage bins may be circular or rectangular. A circular bin can be built of steel plates as a cylinder set on a properly con-

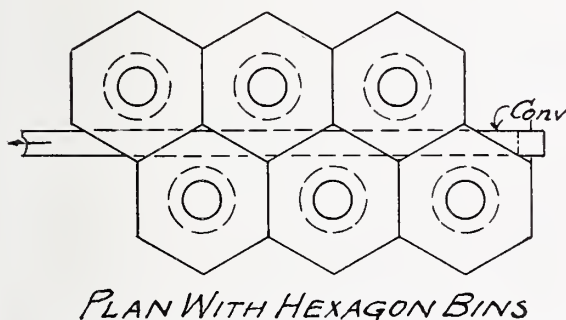
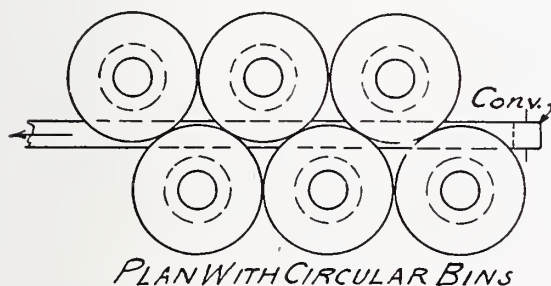
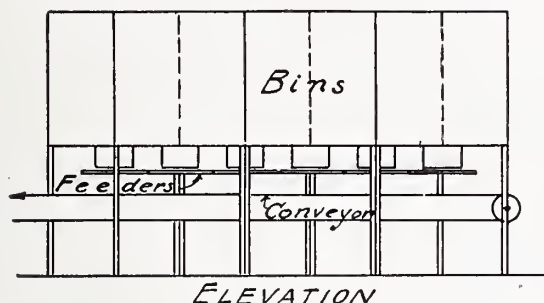


FIG. 3 — Arrangements for storing and mixing.

tructed platform or floor, or a standard galvanized steel tank can be used with a hole cut into its bottom for the passage of the clay to the cylinder of the feeder. Circular bins can also be built like water tanks of wooden staves and iron hoops.

Square or rectangular bins require more material for their construction than circular bins but they often fit better into their surroundings and can be made part of the building. They can be framed and sheathed structures, or cribbed plank laid flat and spiked together. Frame bins should be properly tied with tie rods both ways to prevent their distortion and bulging.

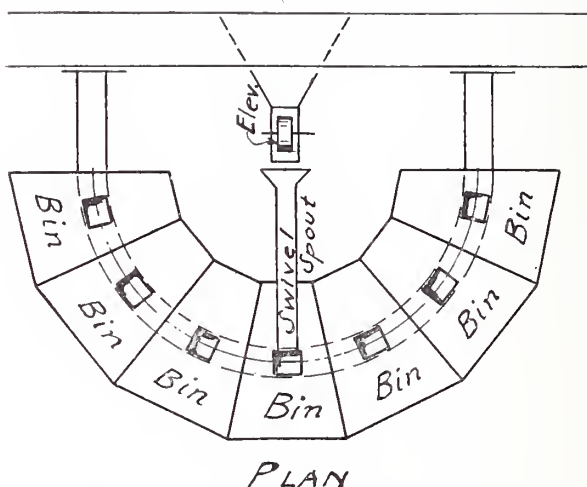


FIG. 4.—Arrangement for storing and mixing.

Circular as well as square bins can also be built of reinforced concrete, or posts and floors can be built of reinforced concrete and an independent frame or steel bin set on top of it.

Examples of Dry Clay Storage

In figure 1 we have a typical arrangement for a brick or tile plant. There is a pocket for the raw material and storage provisions for the crushed shale as well as for the ground shale.

Where a number of different clays are to be used, as in the manufacture of fire-bricks or refractories or pottery, a corresponding number of bins will have to be built, and they can be

arranged in a single row or double row or in a semi-circle depending upon the layout of the plant and the number and size of bins, as seen in the following sketches.

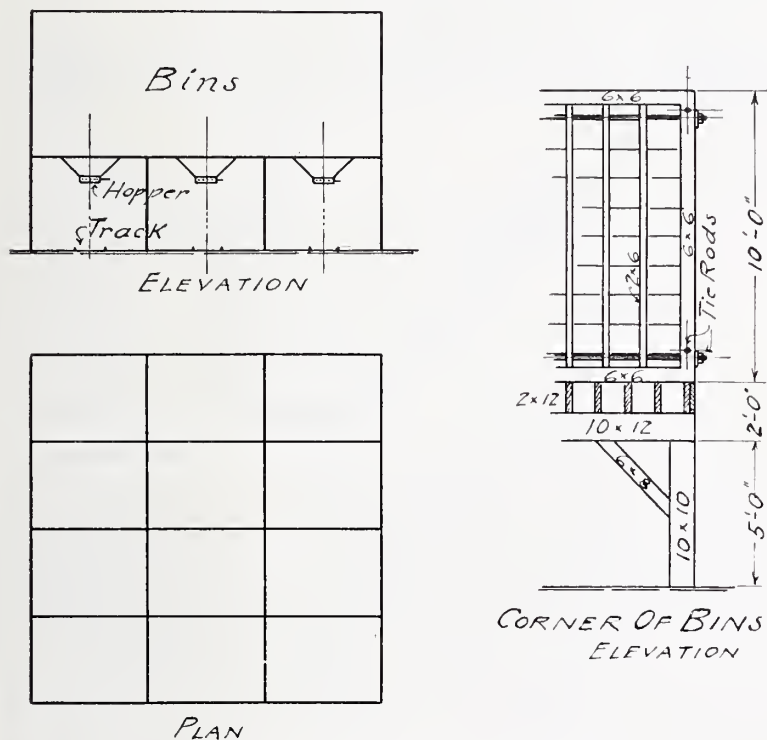


FIG. 5.—Clay bins, assembly and detail.

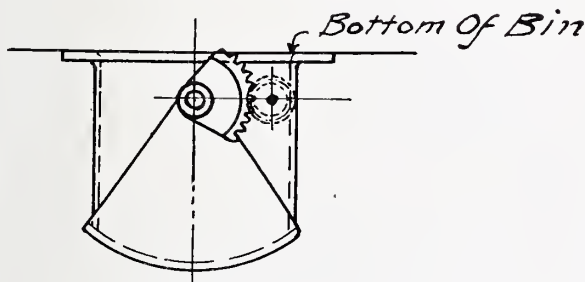


FIG. 6.—Gate for bottom discharge.

In figure 2 we have one row of bins with a disc feeder at the bottom of each bin for supplying the proper quantity of clay to the mixture on the belt.

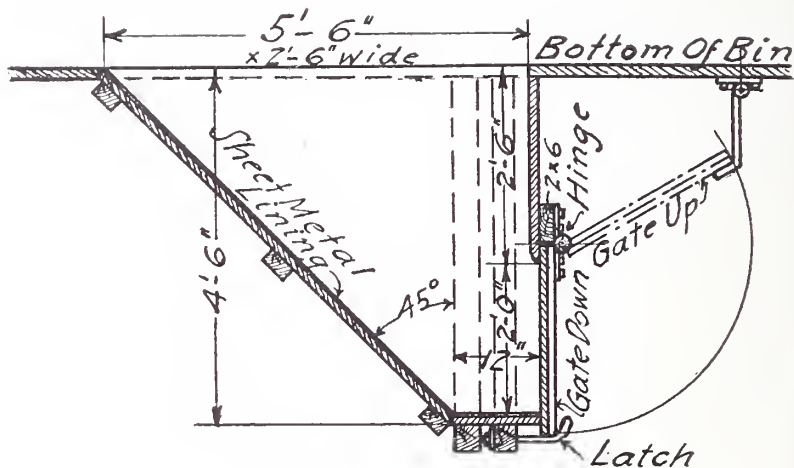


FIG. 7.—Bottom discharge of bin.

In figure 3 there are two rows of bins being charged from a car of the side dump type. Such bins can be square or circular or hexagon. Hexagon bins will utilize the space to greater advantage than circular bins and will reach farther over the conveyor.

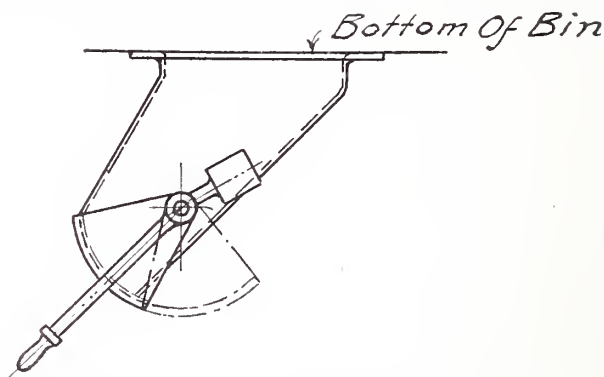


FIG. 8.—Under-cut gate for bottom or side discharge.

Figure 4 shows bins arranged semi-circular around an elevator. The bins can be emptied by feeders as before or by a car (which

can be a measuring car) running on a semi-circular track, to be taken to the pit or pug mill.

In figure 5 we have a larger number of bins arranged in three rows with a track below each. The bins may have a hopper bottom with a slide gate as shown or cast iron outlets may be used as illustrated in figure 6 which are made with either single or double swing-gate. Fine adjustments in the feeding are also

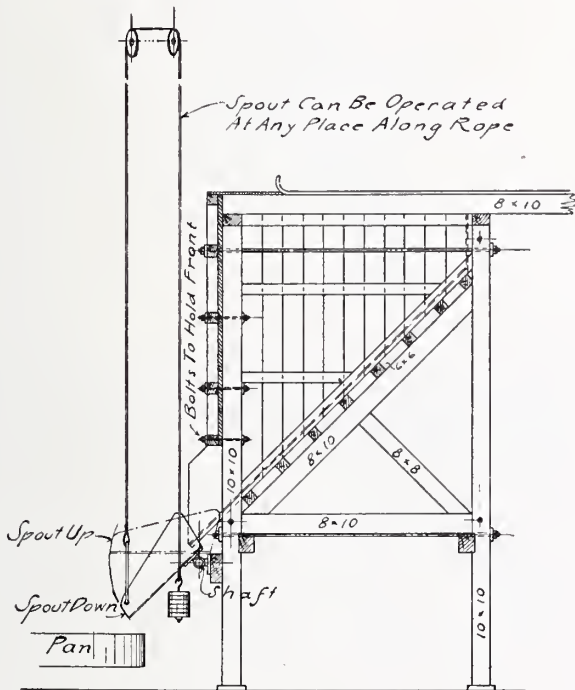


FIG. 9.

accomplished by arrangements as shown in figures 7 and especially 8 which can be used for either bottom discharge or side discharge of bins.

In figure 9 we have an illustration of a bin with an inclined bottom and a side discharge. Such a bin will hold less clay than one with a flat bottom. An inclined bottom will insure a more uniform sliding, while a flat bottom on the other hand will give

additional storage at the corners which can be shoveled out or scraped down in an emergency, should the supply run low. This statement holds good for crushed but not always for finely ground material since some shales which are slightly moist or oily will be

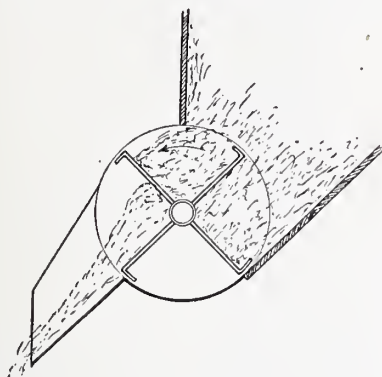


FIG. 11.

packed down by the weight above and the unavoidable, though slight vibrations of the bin structure so that the material from the corners would have to be broken loose and be crushed again. The flow of clay is stopped by merely raising the front spout high

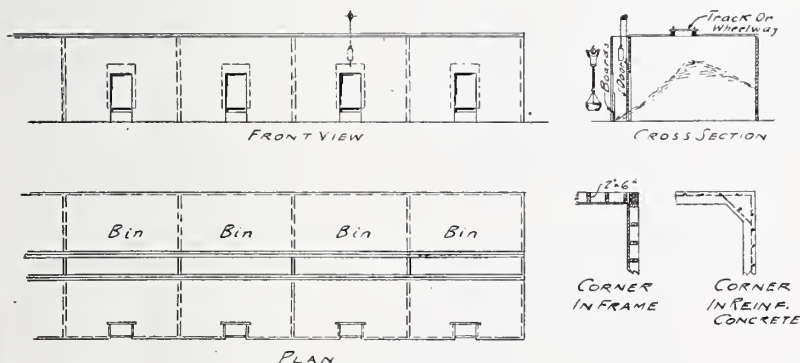


FIG. 12.

enough. Another similar spout, but with an additional slide gate behind for shutting off the supply or for regulating it, is shown in figure 10. Both these gates are counterbalanced.

We have deemed it advisable to go into some details of construction and supply dimensions on the drawings since a good deal of such equipment could be made up in the factory in a manner as shown or any similar manner to suit the requirements.

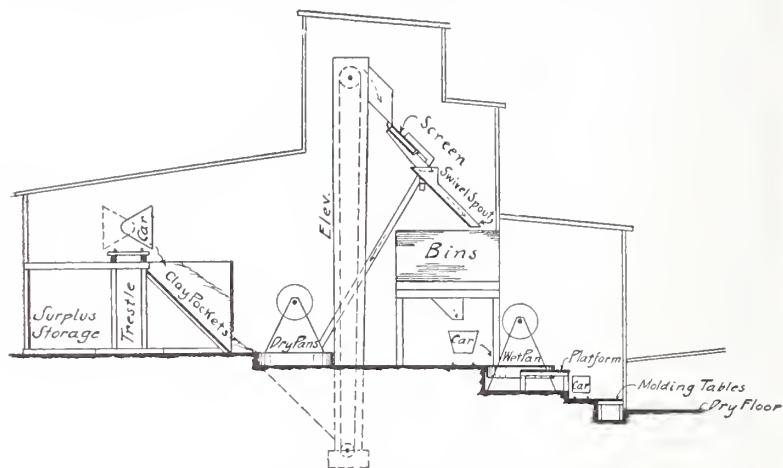


FIG. 13.—Storage in a refractory plant.

In figure 11 we have shown a rotary drum or rotating compartment feeder at the end of a bin spout for feeding a pan or other machinery. By making the drum long enough and introducing side partitions (not shown) we can mix two or three kinds of clay and feed them automatically.

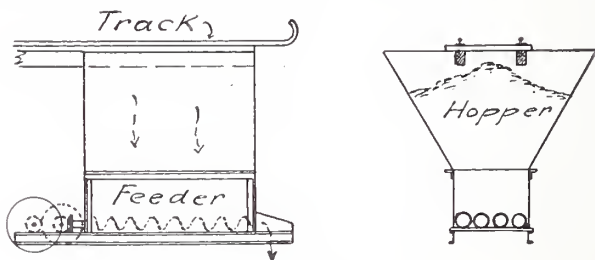


FIG. 14.

In figure 12 we have bins built on the ground or floor, filled from above, intended for fire clays and grogs as used in the manufacture of special refractories, pottery, saggars, etc., requiring

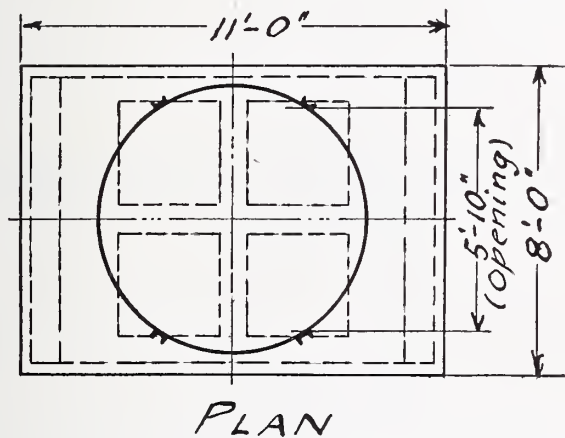
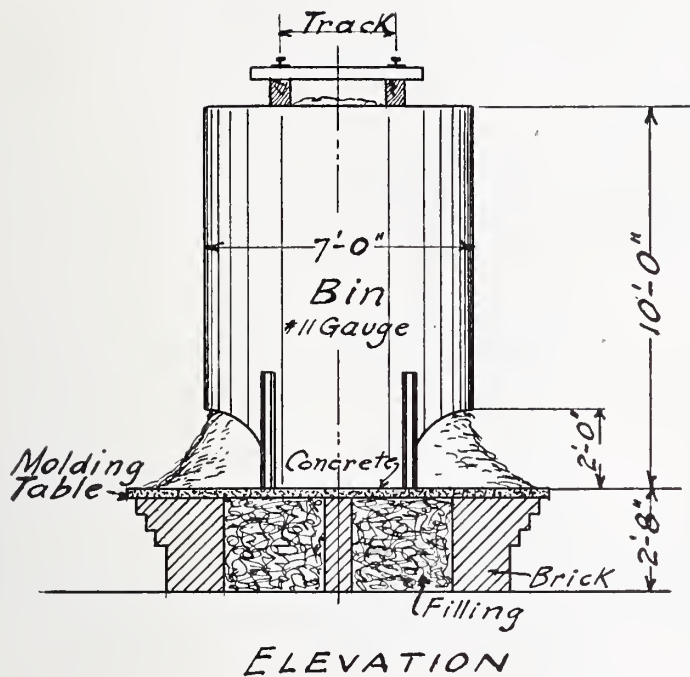


FIG. 15.—Storage above molding table.

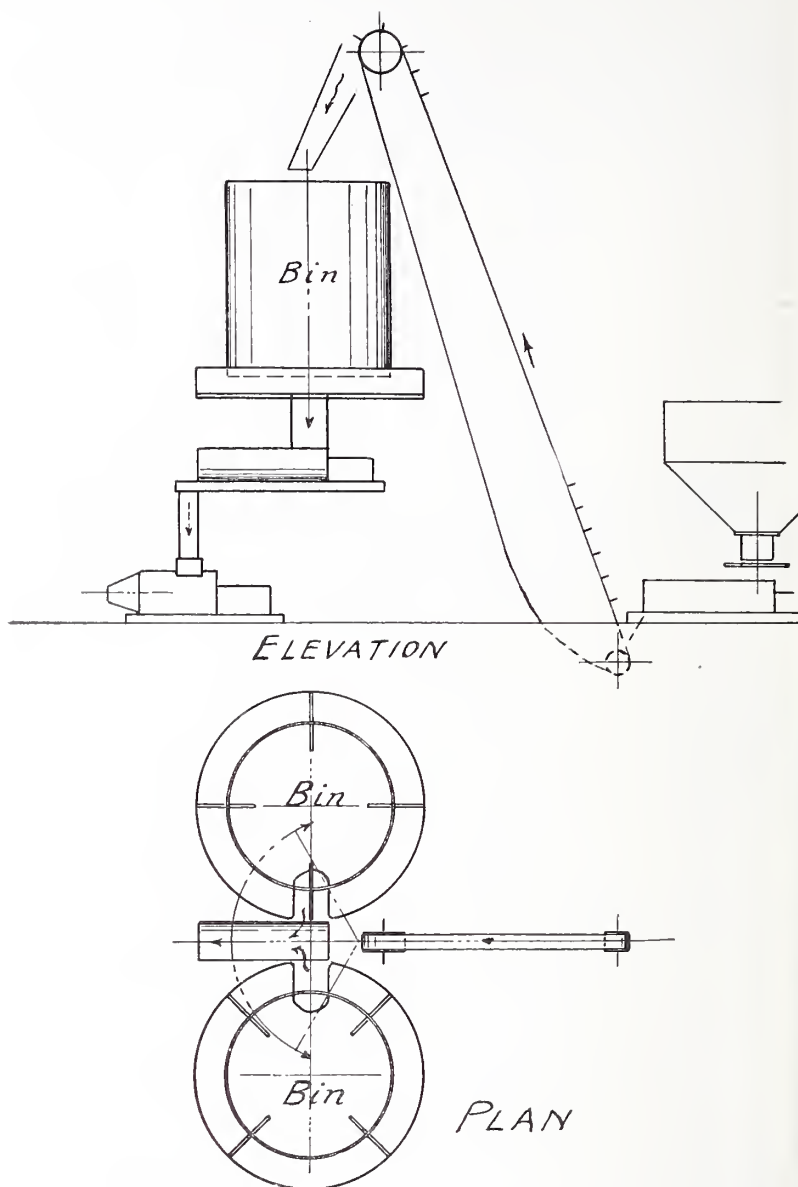


FIG. 16.—Wet clay storage for continuous operation.

a number of clays and variable mixtures. There is a place in front of each bin for scooping up the material and filling it into a wheelbarrow or truck or into a traveling tray of a mono-rail carrier. For large bins, the rail can be extended into the bin's. For this system the material can be weighed at each bin by a scale attached to the tray. If shoveled into wheelbarrows the amount is weighed near the scoop of the mixing machine where the batch is made up. Such bins can be built of frame or of reinforced concrete.

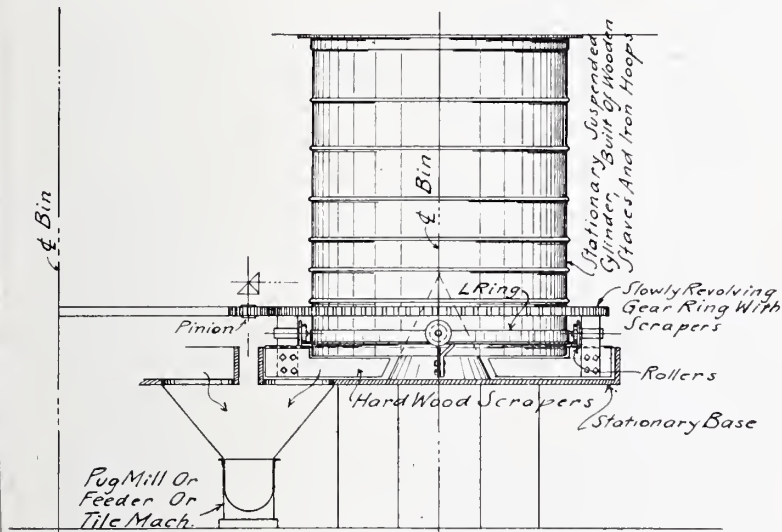


FIG. 17.

Figure 13 shows the arrangement for storing the clays in a small plant for making hand moulded fire-brick and refractories. The drawing explains itself.

Examples of Wet Clay Storage

So far we have been dealing with dry materials but when it comes to the handling and storing of wet clays the problem is more difficult.

While refractory and pottery plants are storing wet clays for the purpose of ageing to improve the working conditions and quality, the storage supply is but a secondary consideration.

Where wet or moist clays are used in the manufacture of brick or tile, they are usually dumped by means of a bottom dump car or by a dumping device into a hopper above a screw feeder as shown in figure 14. There is usually but enough storage provided to last until the return of the car. A screw feeder is adoptable for feeding wet clays where the ordinary disc feeder would not do. If very sticky clays are worked, they would bridge over in a hopper with inclined sides as shown, and it will be necessary here to build the hopper straight.

Figure 15 shows the storage bin for the prepared wet material above the molding table as it is used in silica brick plants.

In figures 16 and 17 finally we have illustrated a suggestion for storing wet clay in a continuous operation for the manufacture of drain tile.

It has been observed that from some shales the first product in the morning, taken from the material which remained in the pug mill over night, does not give the very objectionable ragged ends in the cutting. The duration of one night is evidently sufficient to get all clay particles sufficiently softened to produce the better ware, and it would unquestionably pay in many cases to introduce a wet storage bin without breaking the continuity of the operation.

We have illustrated such an arrangement, in the last two drawings, with two bins and a feeder at the bottom of each. The two bins can be filled and emptied alternately from day to day allowing sufficient storage for each, or both bins can be emptied and filled at the same time. If the capacity of the bins is drawn during the day, the new material, reaching the bottom at the end of the day's run, will remain in the bin over night to be drawn out the next day, and so on. To eliminate the wet clay elevator, the dry material can be elevated to a pug mill above the bins.

While wet pans might accomplish the same, it is obvious that the above system eliminates the great power consumption of wet pans.

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NOTICE—Further discussion of this subject is solicited. All communications should be sent to the Editor.

A CLASSIFICATION OF ENAMELS FOR SHEET STEEL*

By R. R. DANIELSON

An inspection of commercial formulas for sheet steel enamels shows a considerable variation in the chemical composition; in certain instances even in the case of enamels used for the same type of ware. In spite of these permissible variations a study of a large number of commercial formulas shows that there are certain typical classes into which these various compositions can be grouped.

Sheet steel enamels may be classified generally into two rather distinct groups, that is the gray or so called granite ware enamels and the three-coat enamels. In this first group we have a single coat of enamel applied to the metal, and mottled by the formation of rust spots on the metal. This ware is given a single firing when it is finished and ready for the trade. Enamels typical of this group are shown in table 1.

The melted compositions are shown on the same table, it being assumed in computing these that such materials as feldspar, fluorspar and bone ash lose no weight in smelting. Gray enamel A is typical of some of the earlier types of gray ware enamel containing a comparatively high content of quartz in addition to feldspar as a refractory. It contains considerable opacifying agents in the form of fluorspar, bone ash and antimony oxide.

TABLE 1—GRAY WARE ENAMELS

Raw Batch Composition of Frits

| | A | B | C |
|---------------------|-------|-------|-------|
| Feldspar..... | 30.0 | 40.0 | 48 |
| Borax..... | 28.5 | 30.5 | 40 |
| Quartz..... | 19.0 | 10.0 | ... |
| Soda ash..... | 8.0 | 6.5 | 3.0 |
| Sodium nitrate..... | 4.0 | 5.5 | 4.0 |
| Fluorspar..... | 3.0 | 1.5 | ... |
| Bone ash..... | 5.0 | 4.5 | 3.5 |
| Antimony oxide..... | 2.5 | 1.5 | 1.5 |
| Total..... | 100.0 | 100.0 | 100.0 |

Mill Batch: Frit 100.0, clay 6.0, magnesium carbonate 0.25, water 50.0.

* Read at the meeting of the Society at the Chemical Exposition, New York City, Sept. 24, 1920.

Percentage Composition of Melted Frits

| | A | B | C |
|--------------------------------------|-------|-------|-------|
| Feldspar. | 37.2 | 50.3 | 62.05 |
| Quartz. | 23.5 | 12.6 | .. |
| B ₂ O ₃ | 12.8 | 14.1 | 18.9 |
| Na ₂ O. | 13.4 | 13.5 | 12.6 |
| Fluorspar. | 3.7 | 1.9 | .. |
| Bone ash. | 6.3 | 5.7 | 4.5 |
| Antimony oxide. | 3.1 | 1.9 | 1.95 |
| Total. | 100.0 | 100.0 | 100.0 |

TABLE 2—GRAY WARE ENAMELS

Empirical Formulas

| | | | | | |
|---|-----------------------|---|--------------------------------------|---|------------------------------------|
| A | 0.05 K ₂ O | { | 0.103 Al ₂ O ₃ | { | 1.39 SiO ₂ |
| | .77 Na ₂ O | | .312 B ₂ O ₃ | | .079 F ₂ |
| | .18 CaO | | .019 Sb ₂ O ₃ | | .033 P ₂ O ₅ |

1.00

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.46$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 13.5$$

| | | | | | |
|---|------------------------|---|--------------------------------------|---|------------------------------------|
| B | 0.116 K ₂ O | { | 0.228 Al ₂ O ₃ | { | 2.18 SiO ₂ |
| | .676 Na ₂ O | | .545 B ₂ O ₃ | | .065 F ₂ |
| | .208 CaO | | .017 Sb ₂ O ₃ | | .048 P ₂ O ₅ |

1.000

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.0$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 9.56$$

| | | | | | |
|---|------------------------|---|--------------------------------------|---|------------------------------------|
| C | 0.153 K ₂ O | { | 0.310 Al ₂ O ₃ | { | 2.18 SiO ₂ |
| | .721 Na ₂ O | | .805 B ₂ O ₃ | | .042 P ₂ O ₅ |
| | .126 CaO | | .019 Sb ₂ O ₃ | | |

1.000

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 2.7$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 7.03$$

Gray ware enamel B is a type showing the tendency to reduce the amount of quartz and replace it with feldspar. There is apparent a desire to reduce the amount of antimony oxide and of fluorspar, and we note a slight increase in the content of boric

oxide probably to retain a fusing temperature similar to that of enamel A.

Gray enamel C is a type much in use at the present time. Quartz has been eliminated entirely and has been replaced by feldspar which remains as the sole refractory. Fluorspar has been eliminated and the boric acid increased to care for the decrease of other fluxes. It is to be noted in the three types that the content of sodium oxide remains fairly constant, and this is undoubtedly due to the fact that higher amounts of sodium oxide give difficulties from blistering and boiling. The next change in this class of enamels will probably be in the elimination of antimony oxide and its replacement by some opacifying agent to which there is not attached the prejudice now associated with antimony.

The usual mill additions to the gray ware frits consist of about six per cent of some high grade ball clay, one-fourth of one per cent of magnesium carbonate and about one-fourth of one per cent of some electrolyte, such as magnesium sulphate or cobalt and nickel sulphates. These sulphates play a part in tempering the enamel to such a viscosity that it may be properly applied to the steel and also promote rusting of the metal, which gives rise to the mottled granite appearance. Certain plants make use of small amounts of metallic oxides to produce various shades of gray, but the amounts added are usually so small that they do not play any material part in the behavior of the enamel. These oxides are added to the raw enamel batch previous to smelting and may consist of 0.01 to 0.02 per cent of cobalt oxide and 0.2 to 0.3 per cent of nickel, manganese or iron oxides.

The empirical formulas for these three gray ware enamels have been calculated and are shown in table 2. It has been assumed for these and subsequent calculations that all the materials entering into the enamels have approached the theoretical compositions, which is true of most enamel ingredients except that of feldspar. For this we have assumed the composition of an average Connecticut feldspar with the following percentage composition: 71 SiO_2 , 17 Al_2O_3 , 8 K_2O and 4 Na_2O . A study of these empirical formulas shows a slight decrease in the refractoriness, due principally to a decrease in the silica-boric oxide ratio.

TABLE 3—GROUND COATS

Raw Batch Composition of Frits

| | A | B | C |
|----------------------|-------|-------|-------|
| Borax..... | 30.0 | 30.0 | 39.5 |
| Feldspar..... | 22.0 | 27.0 | 20.5 |
| Quartz..... | 29.0 | 20.5 | 22.5 |
| Soda ash..... | 5.0 | 9.8 | 5.0 |
| Soda nitre..... | 4.6 | 5.0 | 4.7 |
| Fluorspar..... | 6.0 | 6.0 | 6.0 |
| Cobalt oxide..... | 0.4 | 0.5 | 0.4 |
| Manganese oxide..... | 2.0 | 1.2 | 1.0 |
| Nickel oxide..... | 1.0 | ... | 0.4 |
| Total..... | 100.0 | 100.0 | 100.0 |

Mill Batch: Frit 100.0, clay 7.0, borax 1.5, water 50.

Percentage Composition of Melted Frits

| | A | B | C |
|-------------------------------------|-------|-------|-------|
| Feldspar..... | 27.2 | 34.3 | 26.9 |
| Quartz..... | 36.0 | 26.2 | 29.6 |
| B ₂ O ₃ | 13.6 | 14.0 | 18.9 |
| Na ₂ O..... | 11.6 | 15.8 | 14.4 |
| CaF ₂ | 7.4 | 7.6 | 7.9 |
| CoO..... | 0.5 | 0.63 | 0.5 |
| MnO..... | 2.47 | 1.5 | 1.3 |
| NiO..... | 1.23 | .. | 0.5 |
| Total..... | 100.0 | 100.0 | 100.0 |

TABLE 4—GROUND COATS

Empirical Formulas

| | | | | | |
|---|--------------------------|---|---------------------------------------|---|------------------------|
| A | 0.5490 Na ₂ O | } | 0.1203 Al ₂ O ₃ | { | 2.445 SiO ₂ |
| | .0615 K ₂ O | | | | |
| | .2530 CaO | | | | |
| | .0164 CoO | | | | |
| | .0757 MnO | | | | |
| | .0444 NiO | | | | |
| | 1.0000 | | | | |

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.73$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 20.3$$

| | | | | | |
|----------|--------------------------|---|---------------------------------------|---|-------------------------|
| <i>B</i> | 0.6399 Na ₂ O | } | 0.1322 Al ₂ O ₃ | { | 1.9200 SiO ₂ |
| | .0673 K ₂ O | | | | |
| | .2260 CaO | | | | |
| | .0182 CoO | | | | |
| | .0486 MnO | | | | |
| | <hr/> | | | | |
| | 1.0000 | | | | |

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.16$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 14.5$$

| | | | | | |
|----------|--------------------------|---|---------------------------------------|---|------------------------|
| <i>C</i> | 0.6222 Na ₂ O | } | 0.1120 Al ₂ O ₃ | { | 2.008 SiO ₂ |
| | .0558 K ₂ O | | | | |
| | .2502 CaO | | | | |
| | .0162 CoO | | | | |
| | .0374 MnO | | | | |
| | .0182 NiO | | | | |
| | <hr/> | | | | |
| | 1.0000 | | | | |

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 3.0$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 17.9$$

Three coat enameled ware, as its name indicates, is coated with three coats, a ground and two cover enamels. The following compositions given in table 3 are typical of ground coats in American practice. They may be grouped according to the type of ware to which they are applied as well as upon their refractoriness.

Ground A is a refractory enamel because of its high content of quartz and low amount of fluxes and for that reason is not adapted to lighter gauge shaped ware or to flat ware, such as signs and stove work, which would tend to buckle in the comparatively high temperature required for its fusion. It is used with success on heavy gauges of shaped ware such as enameled pipe, pails and containers. Because of its high content of metallic oxides, it is a tough durable enamel giving excellent service on ware subjected to hard service.

Ground B is one in use for flat ware such as stove work, table tops and two or three color signs and for medium gauge shaped ware. It is a high sodium oxide enamel with a medium content of refractories and is fired at a medium temperature.

Ground C is a type which has been used on light gauge drawn and spun ware. Because of its high boric oxide content it is not

desirable for the manufacture of flat ware where there is an opportunity for free expansion and contraction of the metal. It has a low fusion temperature, because of its low content of refractories and increased content of fluxes.

The empirical formulas are shown in table 4 and the silica-boric oxide ratios show the increase in boric oxide content.

Cover Enamels

Cover enamels for ordinary three coat ware may be classified in two general groups, as white and colored enamels. The main distinction between these groups is in the content of opacifying agents. The compositions under white enamels shown in table 5 are typical of those which have been used with success and indicate a gradual evolution from the original.

White Enamel A is similar to German enamels in which the feldspar is low and the antimony oxide high. Very often this type is made up with small additions of clay in the raw batch, which would tend to overcome the effect of small amounts of feldspar.

White Enamel B shows an increase in the feldspar content and a decrease in the antimony oxide with the same content of fluorspar and cryolite. The increase in feldspar is compensated for by a decrease in the quartz content.

White Enamel C is a type which is used considerably where a very opaque enamel is demanded. It is the most refractory enamel of the three, carrying increased refractories and a smaller content of borax. This decrease in borax is taken care of by the replacement of fluorspar by cryolite, which exerts a greater fluxing action. Empirical formulas for the white enamels are shown on table 6.

The usual mill additions for these types consist of six per cent of a high grade ball clay or some plastic kaolin, seven per cent of tin oxide and 0.5 per cent of magnesium carbonate which aids in the flotation of the prepared enamels.

Colored Enamels

Colored enamels differ from white enamels in that they are usually low in opacifying agents and hence have taken the name of glass or glass frit. Two types are shown in table 7.

Glass A is one which works well for dark colors because of its small content of opacifying agents. Glass B with its high content of opacifiers serves well for light colored enamels as it tends to mask the dark underlying ground coat. A comparison of glasses A and B shows that the main difference is in the decrease of feldspar and increase of fluorspar and cryolite.

Blue and black enamels are made by adding metallic oxides to the raw batch previous to smelting, while the others are produced by milling some oxide or color stain with the frit in the mills. This is done simply because of the intense coloring effect of cobalt which requires the intimate mixture with the other ingredients that is obtained on smelting.

TABLE 5—WHITE COVER ENAMELS

Raw Batch Composition of Frits

| | A | B | C |
|---------------------|-------|-------|-------|
| Borax..... | 28.0 | 27.0 | 21.0 |
| Feldspar..... | 25.0 | 31.0 | 31.0 |
| Quartz..... | 19.0 | 17.0 | 22.0 |
| Soda ash..... | 3.5 | 3.5 | 3.5 |
| Sodium nitrate..... | 3.5 | 3.5 | 3.5 |
| Fluorspar..... | 5.0 | 5.0 | ... |
| Cryolite..... | 12.0 | 12.0 | 17.0 |
| Antimony oxide..... | 4.0 | 1.0 | 2.0 |
| Total..... | 100.0 | 100.0 | 100.0 |

Mill Batch: Frit 100.0, clay 6.0, tin oxide 7.0, magnesium carbonate 0.5, water 60.0.

Percentages Composition of Melted Frits

| | A | B | C |
|-------------------------------------|-------|-------|-------|
| Feldspar..... | 30.1 | 37.0 | 35.8 |
| Quartz..... | 23.0 | 20.5 | 25.5 |
| B ₂ O ₃ | 12.3 | 11.8 | 8.9 |
| Na ₂ O..... | 9.4 | 9.2 | 7.8 |
| CaF ₂ | 6.0 | 6.0 | ... |
| Cryolite..... | 14.4 | 14.3 | 19.7 |
| Antimony oxide..... | 4.8 | 1.2 | 2.3 |
| Total..... | 100.0 | 100.0 | 100.0 |

TABLE 6—WHITE COVER ENAMELS

Empirical Formulas

| | | | | | |
|---|------------------------|---|--------------------------------------|---|-----------------------|
| A | 0.067 K ₂ O | } | 0.226 Al ₂ O ₃ | } | 1.95 SiO ₂ |
| | .730 Na ₂ O | | .458 B ₂ O ₃ | | .741 F ₂ |
| | .203 CaO | | .044 Sb ₂ O ₃ | | |
| | 1.000 | | | | |

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.27$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 8.64$$

| | | | | | |
|---|------------------------|---|--------------------------------------|---|-----------------------|
| B | 0.084 K ₂ O | } | 0.252 Al ₂ O ₃ | } | 2.03 SiO ₂ |
| | .716 Na ₂ O | | .448 B ₂ O ₃ | | .735 F ₂ |
| | .200 CaO | | .011 Sb ₂ O ₃ | | |
| | 1.000 | | | | |

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.53$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 8.06$$

| | | | | | |
|---|------------------------|---|--------------------------------------|---|-----------------------|
| C | 0.098 K ₂ O | } | 0.337 Al ₂ O ₃ | } | 2.66 SiO ₂ |
| | .902 Na ₂ O | | .398 B ₂ O ₃ | | .880 F ₂ |
| | | | .025 Sb ₂ O ₃ | | |
| | 1.000 | | | | |

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 6.68$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 7.90$$

TABLE 7—GLASS FRITS FOR COLORED ENAMELS

Raw Batch Composition of Frits

| | A | B |
|---------------------|-------|-------|
| Borax..... | 29.0 | 29.0 |
| Feldspar..... | 24.0 | 14.0 |
| Quartz..... | 30.0 | 28.0 |
| Soda ash..... | 10.0 | 10.0 |
| Sodium nitrate..... | 3.0 | 5.0 |
| Fluorspar..... | ... | 7.0 |
| Cryolite..... | 4.0 | 7.0 |
| Total..... | 100.0 | 100.0 |

Mill Batch: Frit 100.0, clay 6.0, magnesium carbonate 0.5, water 50.0, additions of necessary stains or oxides.

Percentage Composition of Melted Frits

| | A | B |
|-------------------------------------|-------|-------|
| Feldspar..... | 30.0 | 17.75 |
| Quartz..... | 37.4 | 35.25 |
| B ₂ O ₃ | 13.15 | 13.7 |
| Na ₂ O..... | 14.45 | 15.7 |
| Fluorspar..... | .. | 8.8 |
| Cryolite..... | 5.0 | 8.8 |
| Total..... | 100.0 | 100.0 |

TABLE 8—GLASS FRITS FOR COLORS

Empirical Formulas

| | |
|---|--|
| $ \begin{array}{r} A \quad 0.917 \text{ Na}_2\text{O} \\ .083 \text{ K}_2\text{O} \\ \hline 1.000 \end{array} \left. \vphantom{\begin{array}{r} 0.917 \\ 0.083 \\ 1.000 \end{array}} \right\} $ | $ \begin{array}{r} 0.202 \text{ Al}_2\text{O}_3 \\ .615 \text{ B}_2\text{O}_3 \end{array} \left\{ \begin{array}{l} 3.17 \text{ SiO}_2 \\ .23 \text{ F}_2 \end{array} \right. $ |
|---|--|

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 5.15$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 15.7$$

| | |
|---|---|
| $ \begin{array}{r} B \quad 0.717 \text{ Na}_2\text{O} \\ .033 \text{ K}_2\text{O} \\ .250 \text{ CaO} \\ \hline 1.000 \end{array} \left. \vphantom{\begin{array}{r} 0.717 \\ 0.033 \\ 0.250 \\ 1.000 \end{array}} \right\} $ | $ \begin{array}{r} 0.111 \text{ Al}_2\text{O}_3 \\ .421 \text{ B}_2\text{O}_3 \end{array} \left\{ \begin{array}{l} 1.75 \text{ SiO}_2 \\ .532 \text{ F}_2 \end{array} \right. $ |
|---|---|

$$\frac{\text{SiO}_2}{\text{B}_2\text{O}_3} = 4.17$$

$$\frac{\text{SiO}_2}{\text{Al}_2\text{O}_3} = 15.8$$

The following figures will give some idea of the methods of obtaining various colors:

Blue: Glass A plus 4 per cent black cobalt oxide and 2 per cent manganese dioxide in raw batch.

Black: Glass A plus 1.5 per cent cobalt oxide, 3.0 per cent manganese oxide, 1 per cent chromium oxide, 0.5 per cent copper oxide and 1.5 per cent iron oxide in raw batch.

The following colors may be produced by additions of oxides or stains to Glass A or B in the mill:

Yellow: 3 to 5 per cent cadmium sulphide.

Green: 3 to 5 per cent chromium oxide.

Other colors may be produced by the addition of from one to five per cent of stain, which may be procured on the market.

Since these stains can not be prepared successfully on a small scale in the individual plants, the various shades of colors can be best produced by the use of these prepared stains.

Summary

In this paper have been given the compositions of typical enamels applied to sheet steel together with reasons for their use. It has not been intended to cover the field of possible composition but it has been the purpose of the writer to present proven compositions which yield the several kinds of commercial enamels and enable the makers of enamels to compare them with their own.

BUREAU OF STANDARDS
WASHINGTON, D. C.

NOTICE.—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

EXPERIMENTS IN AVENTURINE GLAZES*¹

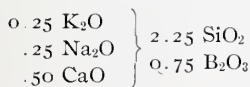
By H. G. SCHURECHT

Introduction

The name "aventurine" as applied to glazes, originated from its similarity in appearance to certain types of quartz and feldspar spangled with scales of mica, hematite or gothite. They give off firelike reflections when held in a bright light and are known as aventurine feldspar and aventurine quartz.

Wöhler² produced glazes having a similar appearance in 1849. Wartha³ obtained an aventurine effect by first applying an engobe of iron or uranium oxide and then covering the same with a borax glaze.

Mäckler⁴ determined the effect of increasing the iron oxide content in glazes of the cone 09 type and found that when 35 parts of iron oxide were added to 100 parts of glazes, he obtained an aventurine effect, but the color of the glaze was too dark, due to the reduction of the iron oxide to the ferrous condition. He, therefore, tried 20 per cent of finely ground metallic iron and obtained a transparent yellow glaze with many goldlike crystals. The glaze used by him corresponded to the following formula:



Patrik⁵ produced artificial crystals of hematite by melting a mixture of iron sulphate and sodium chloride and dissolving in water. Crystals 1 to 2 mm. in diameter were produced in this

* Read Feb. 23, 1920, at the meeting of the Society in Philadelphia.

¹ By permission of the Director, U. S. Bureau of Mines.

² *Thonind. Ztg.*, 1896, p. 219.

³ *Ibid.*, 1890, p. 170.

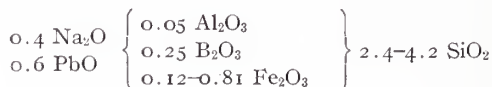
⁴ *Ibid.*, 1890, p. 207.

⁵ *Ibid.*, 1896, 275.

manner. These crystals are not easily dissolved in the glaze melt and when introduced into a glaze appear as bright scales similar to aventurine glazes.

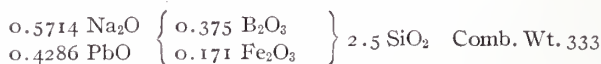
Description of Work

In experiments conducted by the Bureau of Mines the effect of varying iron oxide and silica was studied between the following limits:



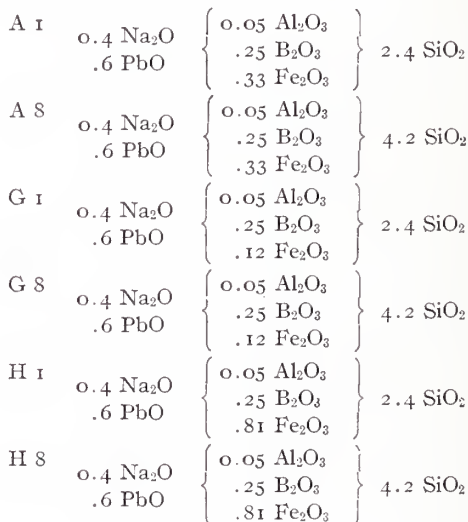
A glaze free from lime was selected as CaO tends to destroy the desirable red or red-brown color in iron glazes.

The frit used is as follows:



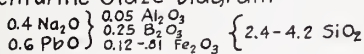
Batch weight: Borax 955, nitrate of soda 933, white lead 1,548, red oxide of iron 384, flint 2,100.

The frit was ground through 100 mesh and used to make up the six end members, which correspond to the following formulas:

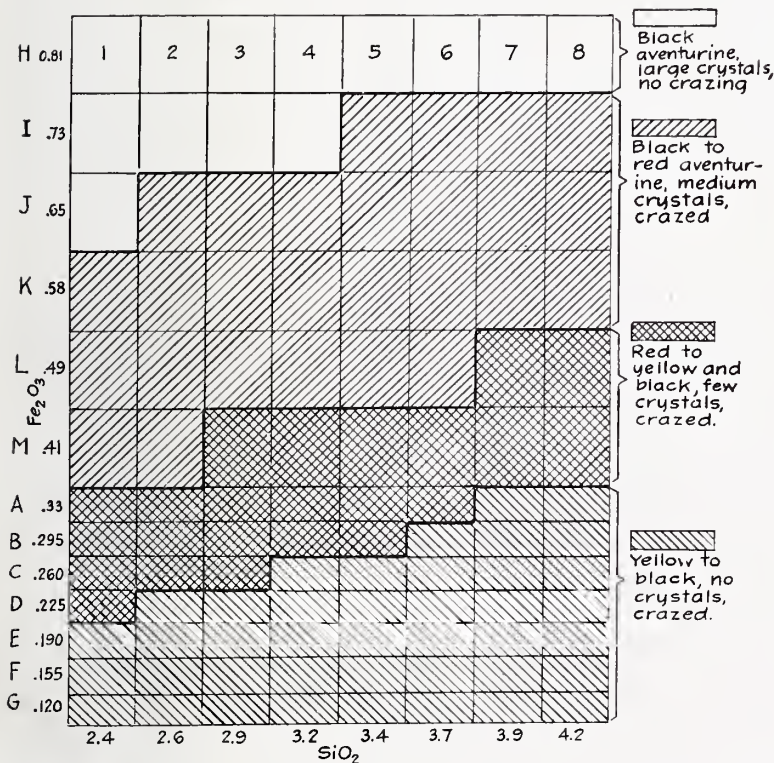


| Batch weight | A 1 | A 8 | G 1 | G 8 | H 1 | H 8 |
|-----------------------|------|------|------|------|------|------|
| Frit..... | 1166 | 1166 | 1166 | 1166 | 1166 | 1166 |
| White lead..... | 387 | 387 | 387 | 387 | 387 | 387 |
| Red oxide of iron.... | 168 | 168 | ... | ... | 552 | 552 |
| Tenn. ball clay..... | 65 | 65 | 65 | 65 | 65 | 65 |
| Flint..... | 165 | 705 | 165 | 705 | 165 | 705 |
| | 1951 | 2491 | 1783 | 2323 | 2335 | 2875 |

Aventurine Glaze Diagram



Burned to cone 4, 1210°C.



These end members were blended in different molecular proportions between the above limits as shown in tables 1 and 2.

The glazes were applied to whiteware trial pieces and fired in glazed saggers to cone 4 under oxidizing conditions. In some

early tests those glazes which contained a maximum of 0.33 Fe_2O_3 were made. No marked crystallization took place, therefore the iron content was increased to 0.81 Fe_2O_3 .

In the diagram are shown the results obtained with the entire field of glazes. Apparently the best crystalline glazes are obtained when more than 0.41 Fe_2O_3 is employed for glazes with 2.4 SiO_2 , and more than 0.58 Fe_2O_3 for glazes containing 4.2 SiO_2 , *i. e.*, for high silica glazes more iron oxide is necessary to produce the aventurine crystal. The trials were fired under oxidizing conditions, but when fired under reducing conditions the tendency is to darken the glaze. A variety of colors varying from red to brown to black may be obtained by varying the kiln atmosphere from oxidizing through mildly reducing to strongly reducing. If the ware is not protected from kiln gases the glazes become a dull black with a metallic luster due to reduction of the ferric oxide to a lower form. If such reduced glazes are covered

TABLE I—Aventurine Glazes

| | A 1 | A 8 | G 1 | G 8 |
|-------|-------|-------|------|------|
| I A 1 | 100.0 | .... | .... | .... |
| I A 2 | 82.5 | 17.5 | .... | .... |
| I A 3 | 66.2 | 33.8 | .... | .... |
| I A 4 | 51.1 | 48.9 | .... | .... |
| I A 5 | 37.0 | 63.0 | .... | .... |
| I A 6 | 23.8 | 76.2 | .... | .... |
| I A 7 | 11.5 | 88.5 | .... | .... |
| I A 8 | .... | 100.0 | .... | .... |
| I B 1 | 84.5 | .... | 15.5 | .... |
| I B 2 | 69.7 | 14.8 | 12.7 | 2.8 |
| I B 3 | 55.9 | 28.6 | 10.2 | 5.3 |
| I B 4 | 43.1 | 41.3 | 7.9 | 7.7 |
| I B 5 | 31.3 | 53.1 | 5.7 | 9.9 |
| I B 6 | 20.1 | 64.2 | 3.7 | 12.0 |
| I B 7 | 9.7 | 74.6 | 1.8 | 13.9 |
| I B 8 | .... | 84.3 | .... | 15.7 |
| I C 1 | 68.6 | .... | 31.4 | .... |
| I C 2 | 56.5 | 12.1 | 25.8 | 5.6 |
| I C 3 | 45.3 | 23.2 | 20.7 | 10.8 |
| I C 4 | 34.9 | 33.5 | 16.0 | 15.6 |
| I C 5 | 25.3 | 43.0 | 11.6 | 20.1 |
| I C 6 | 16.3 | 52.0 | 7.5 | 24.2 |
| I C 7 | 7.9 | 60.4 | 3.6 | 28.1 |

| | | | | |
|-------|------|------|-------|-------|
| I C 8 | .... | 68.2 | .... | 31.8 |
| I D 1 | 52.2 | .... | 47.8 | .... |
| I D 2 | 43.0 | 9.2 | 39.3 | 8.5 |
| I D 3 | 34.5 | 17.6 | 31.5 | 16.4 |
| I D 4 | 26.6 | 26.4 | 24.3 | 23.7 |
| I D 5 | 19.2 | 32.7 | 17.6 | 30.5 |
| I D 6 | 12.4 | 39.5 | 11.3 | 36.8 |
| I D 7 | 6.0 | 45.8 | 5.5 | 42.7 |
| I D 8 | .... | 51.7 | .... | 48.3 |
| I E 1 | 35.4 | .... | 64.6 | .... |
| I E 2 | 29.1 | 6.2 | 53.2 | 11.5 |
| I E 3 | 23.3 | 11.9 | 42.6 | 22.2 |
| I E 4 | 17.9 | 17.2 | 32.8 | 32.1 |
| I E 5 | 13.0 | 22.1 | 23.7 | 41.2 |
| I W 6 | 8.3 | 26.7 | 15.3 | 49.7 |
| I E 7 | 4.0 | 30.9 | 7.4 | 57.7 |
| I E 8 | .... | 34.9 | .... | 65.1 |
| I F 1 | 18.0 | .... | 62.0 | .... |
| I F 2 | 14.8 | 3.1 | 67.5 | 14.6 |
| I F 3 | 11.8 | 6.0 | 54.0 | 28.2 |
| I F 4 | 9.1 | 8.7 | 41.6 | 40.6 |
| I F 5 | 6.6 | 11.2 | 30.0 | 52.2 |
| I F 6 | 4.2 | 13.5 | 19.3 | 63.0 |
| I F 7 | 2.0 | 15.7 | 9.3 | 73.0 |
| I F 8 | .... | 17.7 | .... | 82.3 |
| I G 1 | .... | .... | 100.0 | .... |
| I G 2 | .... | .... | 82.2 | 17.8 |
| I G 3 | .... | .... | 65.7 | 34.3 |
| I G 4 | .... | .... | 50.6 | 49.4 |
| I G 5 | .... | .... | 36.5 | 63.5 |
| I G 6 | .... | .... | 23.5 | 76.5 |
| I G 7 | .... | .... | 13.9 | 86.1 |
| I G 8 | .... | .... | .... | 100.0 |

TABLE 2—Aventurine Glazes

| | H 1 | H 8 | A 1 | A 8 |
|-------|--------|--------|-------|------|
| I H 1 | 100.00 | ... | ... | ... |
| I H 2 | 83.12 | 16.88 | ... | ... |
| I H 3 | 67.00 | 33.00 | ... | ... |
| I H 4 | 52.20 | 47.80 | ... | ... |
| I H 5 | 38.05 | 61.95 | ... | ... |
| I H 6 | 24.98 | 75.02 | ... | ... |
| I H 7 | 12.03 | 87.97 | ... | ... |
| I H 8 | ... | 100.00 | ... | ... |
| I I 1 | 85.80 | ... | 14.20 | ... |
| I I 2 | 71.21 | 14.45 | 11.80 | 2.54 |

TABLE 2 (Continued)

| | H 1 | H 8 | A 1 | A 8 |
|-------|-------|-------|-------|--------------------|
| I I 3 | 57.48 | 28.07 | 9.90 | 4.66 |
| I I 4 | 44.54 | 41.08 | 7.30 | 7.08 |
| I I 5 | 32.53 | 53.07 | 5.40 | 9.10 |
| I I 6 | 21.02 | 64.27 | 3.47 | 11.12 |
| I I 7 | 10.24 | 75.06 | 1.70 | 13.00 |
| I I 8 | ... | 85.23 | ... | 14.77 |
| I J 1 | 70.71 | ... | 29.29 | ... |
| I J 2 | 57.44 | 11.68 | 25.83 | 5.05 |
| I J 3 | 47.30 | 23.10 | 19.60 | 10.00 |
| I J 4 | 36.67 | 33.57 | 15.20 | 14.56 |
| I J 5 | 26.58 | 43.27 | 11.02 | 19.13 |
| I J 6 | 17.28 | 52.76 | 7.18 | 22.83 |
| I J 7 | 8.42 | 61.17 | 3.52 | 26.84 |
| I J 8 | ... | 69.78 | ... | 30.22 |
| I K 1 | 55.37 | ... | 44.53 | ... |
| I K 2 | 45.30 | 9.22 | 37.53 | 7.95 |
| I K 3 | 36.50 | 17.82 | 30.23 | 15.45 |
| I K 4 | 28.27 | 25.89 | 23.42 | 22.42 |
| I K 5 | 20.55 | 33.45 | 17.02 | 28.98 |
| I K 6 | 13.34 | 40.54 | 10.96 | 35.14 |
| I K 7 | 6.44 | 47.26 | 5.35 | 40.95 |
| I K 8 | ... | 53.58 | ... | 46.42 |
| I L 1 | 33.55 | ... | 66.45 | ... |
| I L 2 | 31.12 | 6.33 | 51.58 | 10.97 |
| I L 3 | 25.06 | 12.23 | 41.51 | 21.23 [*] |
| I L 4 | 19.38 | 17.75 | 32.12 | 30.75 |
| I L 5 | 14.07 | 22.91 | 23.31 | 39.71 |
| I L 6 | 9.10 | 27.75 | 15.06 | 48.09 |
| I L 7 | 4.44 | 31.92 | 7.35 | 56.29 |
| I L 8 | ... | 36.65 | ... | 63.35 |
| I M 1 | 19.45 | ... | 80.55 | ... |
| I M 2 | 16.02 | 8.26 | 66.50 | 14.16 |
| I M 3 | 12.90 | 6.30 | 53.60 | 27.30 |
| I M 4 | 9.98 | 9.13 | 41.32 | 39.57 |
| I M 5 | 7.23 | 11.78 | 29.97 | 51.02 |
| I M 6 | 4.63 | 14.25 | 19.33 | 61.78 |
| I M 7 | 2.27 | 16.57 | 9.37 | 71.78 |
| I M 8 | ... | 18.75 | ... | 81.25 |

with a thin coating of a raw lead glaze of the following composition and fired under oxidizing conditions, a maroon color is obtained.

| | |
|----------------------|--|
| 0.6 PbO | } Cone 02 0.2 Al ₂ O ₃ 2.0 SiO ₂ |
| .15 K ₂ O | |
| .10 CaO | |
| .15 FeO | |

Increasing the iron content seems to increase the size and number of crystals in the glaze and also requires a higher temperature for its development.

Slow cooling seems essential for the development of large crystals.

Summary

Within the foregoing experimental limits aventurine glazes were obtained with more than 0.41 Fe_2O_3 in glazes containing 2.4 SiO_2 , and with more than 0.58 Fe_2O_3 in glazes containing 4.2 SiO_2 .

Glazes with 0.41 to 0.73 Fe_2O_3 vary in color from red to black according to kiln conditions, red being produced under oxidizing conditions and black under reducing conditions.

With strong reducing conditions the glazes high in iron become a dull black with a metallic luster. By applying a thin coating of a cone 02 lead glaze on the surface of such a glaze and firing in an oxidizing atmosphere, a maroon effect is obtained.

Increasing the iron content increases the size and number of crystals and also the refractoriness of the glaze.

In conclusion the author wishes to acknowledge his indebtedness to Mr. R. T. Stull for assistance in this work.

CERAMIC LABORATORIES, U. S. BUREAU OF MINES
MINING EXPERIMENT STATION, COLUMBUS, OHIO

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

TIME AND TEMPERATURE OF BURNING AS FACTORS INFLUENCING THE CONSTITUTION AND MICRO- STRUCTURE OF A PORCELAIN BODY*

By A. A. KLEIN

In Technologic Paper of the Bureau of Standards No. 80 by the writer on the constitution and micro-structure of porcelain, it is concluded that the effect of higher temperatures on determining the constitution and micro-structure of a porcelain body is of much greater importance than the length of time of soaking at the maximum temperature. Some exceptions have been taken to this conclusion, namely by Peck¹ and by Mellor.² The conclusions reached by both of these investigators indicated that the time of soaking was a very important factor, perhaps even as important as the actual maximum temperature of burning.

During the past year the writer had occasion to examine a body containing flint, feldspar and clay which had been subjected to successive burning at the same temperature. The data really confirmed those reached in Technologic Paper No. 80.

Owing to the pressure of other work it was impossible to make a very broad investigation of this point; but the Onondaga Pottery Company was communicated with, and through the courtesy of Mr. Pass, several samples of green tableware were procured.

These were burned in a kiln fired to cone 13-14, the temperature as determined by pyrometer being close to 1348° C. In this kiln the soaking period varied from 12 to 18 hours. Six samples were put through one burn, five through two, four through three and so on. Thus there was obtained a collection of samples which had been through from one to six burns. The soaking periods, therefore, were from 12-18 hours to 72-108 hours. In addition one sample was fired in a gas fired pot furnace to cone 15 soaking one hour.

* Received Feb. 27, 1920.

¹ *Jour. Amer. Ceram. Soc.*, 2, 175-194 (1919).

² *Trans. Amer. Ceram. Soc.*, 16, 71 (1914).

The following facts were observed with the body subjected to one burn at cone 13-14 (see figures 1 and 2). The feldspar had

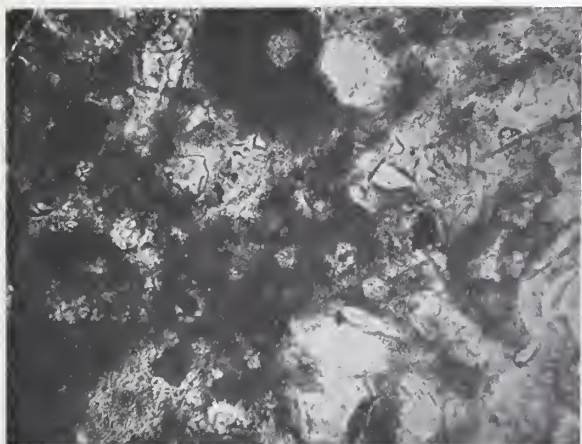


FIG. 1.—Showing body given one burn at cone 13-14 taken in ordinary light. Note the translucent character of the glass due to amorphous sillimanite. Note also the angularity of the quartz grains. Magnification = 200 diameters.



FIG. 2.—Same as figure 1 but taken in plane polarized light with crossed nicols. This brings out some of the quartz grains which are not in extinction.

completely melted and formed a glass. The kaolin had completely dissociated with the formation of amorphous sillimanite predominating and an extremely small amount of fine crystalline

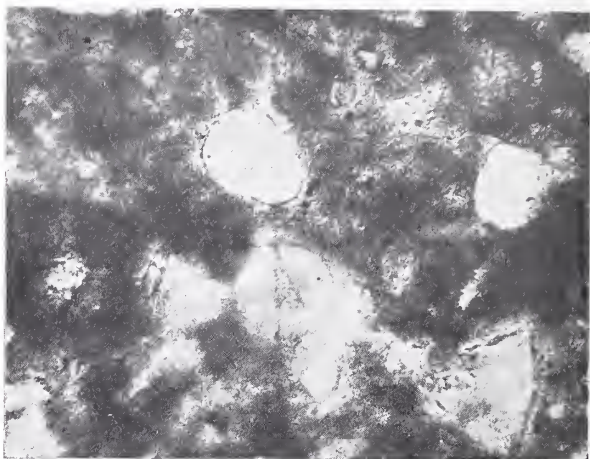


FIG. 3.—Showing body given 3 burns of cone 13-14. Note the similarity of the data with those of figure 1. Magnification = 200 diameters.



FIG. 4.—Showing body given 4 burns at cone 13-14. Note the similarity to figure 1. Magnification = 200 diameters.

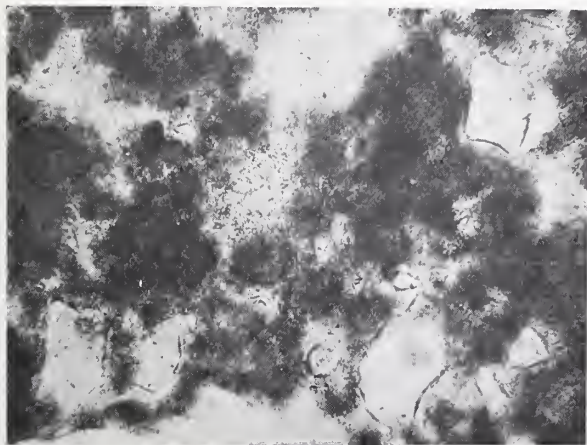


FIG. 5.—Showing body burned 5 times at cone 13-14 taken in ordinary light. Note the small amount of sillimanite crystals and the rather small progress of quartz solution. Magnification = 200 diameters.

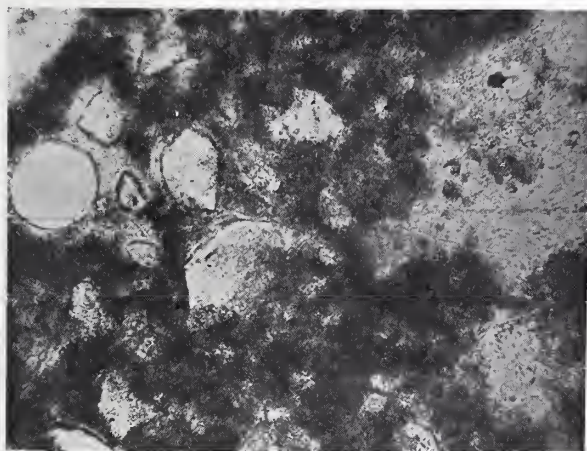


FIG. 6.—Showing body burned 6 times at cone 13-14 taken in ordinary light. Note the similarity of data to those of figure 5. Magnification = 200 diameters.

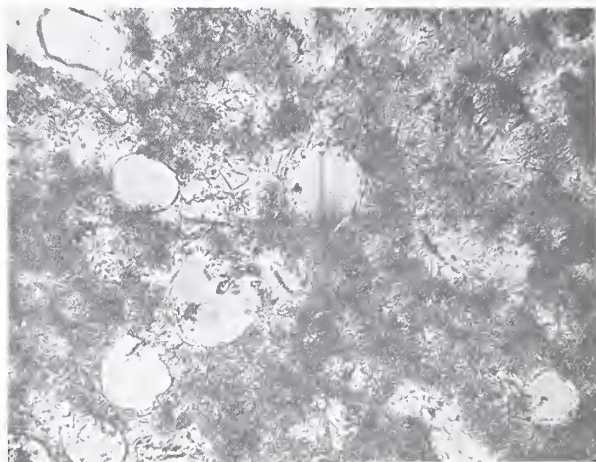


FIG. 7.—Showing body soaked one hour (direct fire) at cone 15 taken in ordinary light. Note the amount and development of sillimanite crystals as well as the amount of quartz solution and its effect upon the contour of the quartz grains. Magnification = 200 diameters.

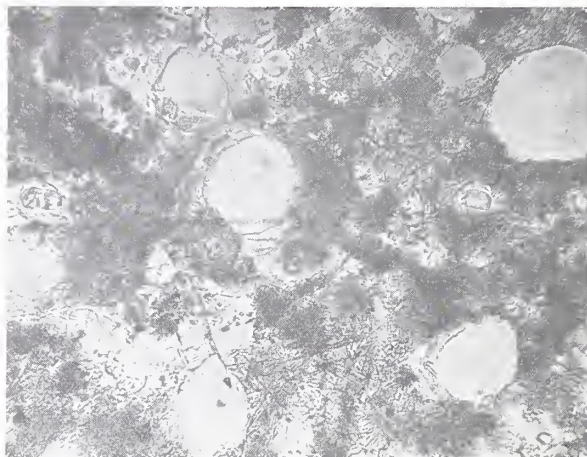


FIG. 8.—Showing body soaked one hour (muffled) at cone 15. Compare with figure 6. Magnification = 200 diameters.

sillimanite. Furthermore, with the exception of a small amount of quartz solution in the very small grains, there was practically no evidence of this phenomenon.

The effect of the additional burns through six times (see figures 3, 4, 5, 6) was substantially as follows. There was a small increase in the amount as well as the development of sillimanite crystals, but in every case the amorphous material predominated. There was also a decrease in the amount of quartz present as the number of burns increased, the amount being determined quantitatively as follows, approximately 30 per cent for the sample burned once as against about 15 per cent for that burned six times. As may be expected the outlines of the quartz grains upon repeated burning showed more and more rounding due to solution.

The data found with the body burned at cone 15 (see figures 9, 10) soaked for one hour differed materially from those of the body given the maximum soaking at the lower temperature. Practically no amorphous sillimanite was present and the crystals of this constituent attained comparatively considerable size. Only the larger quartz crystals still remained and these showed the typical elliptical outlines resulting from profound solution. The amount of this constituent was approximately six per cent.

The accompanying photographs bring out these points and show conclusively that the difference between the short burn at high temperature and six burns at the lower temperature was by far greater than the difference between one and six burns at the lower temperature. We, therefore, feel justified in stating at least for this body, which is a typical American tableware body, that the actual temperature of burning has a much more marked effect on its constitution and structure than the time of soaking.

NORTON COMPANY
WORCESTER, MASS.

NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

RESULTS OF TESTING GYPSUM PRODUCTS*

BY W. E. EMLEY AND C. F. FAXON

In an effort to write standard specifications for gypsum, many difficulties have been encountered. Probably the greatest source of confusion was the attempt to adopt verbatim the standard methods of test which were in use in the examination of other similar materials. Experience showed the futility of this procedure, and finally compelled the invention of new methods of test, designed especially for gypsum. After considerable deliberation and experiment, a number of methods of test were finally agreed upon and adopted as tentative.¹

It then developed that no one had had enough experience with these new methods to be able to predict what numerical results they would give. For example, take the tensile strength. This property of gypsum was pretty well known when measured by any one of several different methods. The method adopted, however, introduced certain innovations, so that no one could foretell just what tensile strength a given sample of material would have when tested by this new method.

Obviously some information about these numerical results was essential, in order that specifications could be intelligently written. It would be absurd to specify a tensile strength of 300 pounds per square inch, and then discover that either all or none of the gypsum on the market met the requirement.

Accordingly the Bureau of Standards undertook to test a number of commercial samples. This article is a compilation of the results obtained. The tests were carried out on 43 samples, made by three different manufacturers. Of these, 25 were shipped to us direct from the factory, packed in air-tight glass containers; 8 came direct from the factory, in the usual commercial package; and 10 were obtained from dealers.

* Received Sept. 1, 1920.

¹ American Society for Testing Materials, C-26-19T.

While an attempt was made to follow the methods of test cited above, certain changes and additions were found advisable and were accordingly made. A brief description of the methods is as follows:

1. Chemical Analysis.—Lime, sulphuric anhydride, carbon dioxide, and loss on ignition, were determined by the usual methods of chemical analysis.¹ These constituents were then combined as follows: The amount of lime required to combine with the carbon dioxide was found by multiplying the per cent carbon dioxide by 56/44. The per cent lime present as carbonate was deducted from the total per cent lime. The per cent water was found by subtracting the per cent carbon dioxide from the per cent loss on ignition. From the figures for lime, sulphuric anhydride, and water, the maximum possible content of calcined gypsum ($\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$) was calculated, using the ratios 56:80:9. Usually two, and always one of these three ingredients was found to be in excess of these ratios. This was taken to indicate the presence of some foreign material, such as calcium hydroxide, magnesium sulphate, anhydrous calcium sulphate, etc.

2. Normal Consistency.—This is the number of cubic centimeters of water which must be added to 100 grams of dry material to produce a paste of standard "wetness." It was determined by means of the Southard viscosimeter,² the standard wetness being such that the final radius of the pat was 9.6 cms.

3. Time of Set.—This is measured by means of a Vicat needle, on material of normal consistency. It is the elapsed time from when the sample is added to the water to when the needle fails to penetrate to the bottom of the pat.

4. Fineness.—This is expressed as the per cent by weight of the material separated by six sieves of different meshes. The sieves used were the Nos. 8, 14, 28, 48, 100 and 200. In general, the material could be screened dry through Nos. 8 and 14, but had to be washed with kerosene in order to get clean separations on the finer sieves.

¹ Hillebrand, "Analysis of Silicate and Carbonate Rocks," U. S. Geol. Sur., *Bull.* 700.

² A. S. T. M., C26-19T.

5. Compressive Strength.—Three cylinders, 2 inches in diameter by 4 inches high, were made of paste of normal consistency. They were removed from the molds as soon as they were hard enough to handle (1 to 24 hours), stored in the air in the room for one week, and tested. The results are expressed as pounds square inch.

TABLE I

| Lab. No. | Trade name of material | Class |
|----------|---------------------------------------|--|
| 1 | Unretarded gauging plaster | } Calcined gypsum only |
| 2 | Molding plaster | |
| 10 | Unretarded gauging plaster | |
| 11 | Molding plaster | |
| 19 | Unretarded gauging plaster | |
| 20 | Molding plaster | |
| 26 | Stucco | |
| 28 | Molding plaster | |
| 29 | Reground stucco | |
| 31 | Stucco | |
| 32 | Stucco | |
| 34 | Plaster of Paris F | |
| 35 | Plaster of Paris FFF | |
| 37 | Windsor cement FFF | |
| 43 | Potters plaster | |
| Ave. | | |
| 3 | Retarding gauging plaster | } Calcined gypsum plus retarder |
| 4 | Cement plaster, unsanded, not fibered | |
| 12 | Retarded gauging plaster | |
| 13 | Cement plaster, unsanded, not fibered | |
| 21 | Retarded gauging plaster | |
| 22 | Cement plaster, unsanded, not fibered | |
| 38 | Ready finish | |
| 41 | Superfine Windsor cement | |
| Ave. | | |
| 5 | Cement plaster, unsanded, fibered | } Calcined gypsum plus retarder plus fiber |
| 16 | Retarded fibered cement plaster | |
| 23 | Fibered cement plaster | |
| 27 | Fibered plaster | |
| 33 | Fibered plaster | |
| 36 | Windsor cement, neat | |
| Ave. | | |

| | | |
|------|---|--|
| 6 | Wood fiber plaster to be used with sand | } Calcined gypsum plus retarder plus wood fiber |
| 7 | Wood fiber plaster | |
| 14 | Wood fiber plaster to be used with sand | |
| 15 | Retarded wood fiber plaster | |
| 24 | Wood fiber plaster to be used with sand | |
| 25 | Wood fiber cement | |
| 30 | Wood fiber plaster | |
| 39 | Windsor cement for concrete | } Calcined gypsum plus retarder plus sand |
| 42 | Wood fiber plaster | |
| Ave. | | |
| 9 | Ready mixed brown coat | } Calcined gypsum plus retarder plus sand |
| 18 | Ready mixed brown coat | |
| Ave. | | |
| 8 | Ready mixed scratch coat | } Calcined gypsum plus retarder plus fiber plus sand |
| 17 | Ready mixed scratch coat | |
| 40 | Brown mortar | |
| Ave. | | |

TABLE 2

Chemical analysis

| Lab. No. | Found | | | | Calculated | |
|----------|-------|-----------------|-----------------|------------------|-----------------|-----------------------------------|
| | CaO | CO ₂ | SO ₃ | Loss on ignition | Calcined gypsum | Constituents in excess |
| 1..... | 37.60 | 4.21 | 48.73 | 10.40 | 83.50 | SO ₃ .H ₂ O |
| 2..... | 37.20 | 4.22 | 49.00 | 10.70 | 82.40 | SO ₃ .H ₂ O |
| 10..... | 34.80 | 12.53 | 36.80 | 16.20 | 48.77 | SO ₃ .H ₂ O |
| 11..... | 35.28 | 11.00 | 38.55 | 16.40 | 55.10 | SO ₃ .H ₂ O |
| 19..... | 38.12 | 0.56 | 53.50 | 8.00 | 97.02 | CaO.H ₂ O |
| 20..... | 38.24 | .74 | 53.64 | 8.00 | 86.60 | SO ₃ .H ₂ O |
| 26..... | 38.20 | .10 | 54.00 | 7.60 | 97.88 | CaO.H ₂ O |
| 28..... | 37.94 | .10 | 53.90 | 7.70 | 97.69 | CaO.H ₂ O |
| 29..... | 35.80 | 2.40 | 47.80 | 9.20 | 84.83 | SO ₃ .H ₂ O |
| 31..... | 37.44 | 0.60 | 51.90 | 7.90 | 94.07 | CaO.H ₂ O |
| 32..... | 37.10 | 4.10 | 48.70 | 10.60 | 82.54 | SO ₃ .H ₂ O |
| 34..... | 38.00 | 1.00 | 51.65 | 7.53 | 93.65 | CaO.H ₂ O |
| 35..... | 38.26 | 0.62 | 53.70 | 6.91 | 97.10 | SO ₃ .H ₂ O |
| 37..... | 38.13 | .53 | 53.80 | 6.94 | 97.00 | SO ₃ .H ₂ O |
| 43..... | 38.90 | .70 | 53.60 | 7.55 | 97.15 | CaO.H ₂ O |
| Ave..... | 37.41 | 2.89 | 49.98 | 9.44 | 87.02 | |
| 3..... | 37.04 | 4.53 | 48.28 | 10.90 | 83.50 | SO ₃ .H ₂ O |
| 4..... | 36.72 | 4.37 | 47.90 | 10.75 | 80.60 | SO ₃ .H ₂ O |
| 12..... | 34.52 | 10.02 | 36.49 | 17.35 | 56.35 | SO ₃ .H ₂ O |
| 13..... | 34.84 | 12.33 | 37.56 | 16.55 | 49.58 | SO ₃ .H ₂ O |
| 21..... | 38.60 | 0.81 | 53.30 | 7.55 | 96.60 | CaO.H ₂ O |
| 22..... | 38.28 | .84 | 53.74 | 8.10 | 96.40 | SO ₃ .H ₂ O |

TABLE 2 (Continued)

| Lab. No. | Chemical analysis | | | | | |
|----------|-------------------|-----------------|-----------------|------------------|-----------------|-----------------------------------|
| | Found | | | Loss on ignition | Calculated | |
| | CaO | CO ₂ | SO ₃ | | Calcined gypsum | Constituents in excess |
| 38..... | 39.20 | 2.83 | 15.55 | 14.20 | 28.20 | CaO.H ₂ O |
| 41..... | 35.72 | 15.20 | 35.90 | 20.05 | 42.38 | SO ₃ .H ₂ O |
| Ave..... | 36.86 | 6.37 | 41.09 | 13.18 | 66.70 | |
| 5..... | 36.96 | 4.73 | 47.83 | 11.15 | 80.20 | SO ₃ .H ₂ O |
| 16..... | 35.00 | 12.16 | 37.90 | 17.15 | 50.56 | SO ₃ .H ₂ O |
| 23..... | 36.88 | 0.68 | 52.30 | 7.35 | 93.30 | SO ₃ .H ₂ O |
| 27..... | 38.24 | .40 | 53.90 | 7.90 | 97.68 | SO ₃ .H ₂ O |
| 33..... | 37.70 | .10 | 53.40 | 7.80 | 96.79 | CaO.H ₂ O |
| 36..... | 36.88 | 1.40 | 48.50 | 8.18 | 87.95 | CaO.H ₂ O |
| Ave..... | 36.94 | 3.24 | 48.97 | 9.92 | 84.41 | CaO.H ₂ O |
| 6..... | 36.92 | 4.36 | 48.52 | 10.70 | 81.20 | SO ₃ .H ₂ O |
| 7..... | 37.00 | 4.41 | 48.59 | 10.50 | 81.25 | SO ₃ .H ₂ O |
| 14..... | 34.96 | 12.64 | 37.32 | 17.35 | 48.86 | SO ₃ .H ₂ O |
| 15..... | 35.12 | 11.90 | 38.10 | 17.40 | 51.70 | SO ₃ .H ₂ O |
| 24..... | 38.20 | 0.74 | 53.64 | 7.90 | 96.47 | SO ₃ .H ₂ O |
| 25..... | 38.08 | .82 | 53.06 | 7.95 | 95.95 | SO ₃ .H ₂ O |
| 30..... | 36.14 | 2.50 | 48.40 | 9.40 | 85.34 | SO ₃ .H ₂ O |
| 39..... | 27.41 | 1.64 | 27.70 | 9.25 | 50.22 | CaO.H ₂ O |
| 42..... | 35.40 | 1.31 | 46.40 | 8.60 | 84.10 | CaO.H ₂ O |
| Ave..... | 35.47 | 4.48 | 44.64 | 11.01 | 75.01 | CaO.H ₂ O |
| 9..... | 18.20 | 10.86 | 13.49 | 13.10 | 11.27 | SO ₃ .H ₂ O |
| 18..... | 25.60 | 15.70 | 13.68 | 17.80 | 14.50 | SO ₃ .H ₂ O |
| Ave..... | 21.90 | 13.28 | 13.58 | 15.45 | 12.88 | |
| 8..... | 18.52 | 10.32 | 14.80 | 12.75 | 13.92 | SO ₃ .H ₂ O |
| 17..... | 24.80 | 13.86 | 15.84 | 16.70 | 18.49 | SO ₃ .H ₂ O |
| 40..... | 8.76 | 0.47 | 10.80 | 3.09 | 19.58 | CaO.H ₂ O |
| Ave..... | 17.36 | 8.22 | 13.81 | 10.85 | 17.33 | |

TABLE 3

| Lab. No. | Fineness | | | | | | Through 200 |
|----------|----------|------|-------|-------|--------|---------|-------------|
| | On 8 | 8-14 | 14.28 | 28-48 | 48-100 | 100-200 | |
| 1..... | ... | 0.1 | 0.1 | 0.9 | 3.9 | 15.4 | 79.6 |
| 2..... | ... | ... | .2 | 1.1 | 4.1 | 8.2 | 86.4 |
| 10..... | ... | .1 | .3 | 4.6 | 7.0 | 11.5 | 76.5 |
| 11..... | ... | .1 | .1 | .3 | 0.7 | 6.8 | 92.0 |
| 19..... | ... | .1 | .3 | 3.0 | 24.0 | 26.7 | 45.9 |
| 20..... | ... | ... | .1 | 0.5 | 6.3 | 23.2 | 69.9 |

TESTING GYPSUM PRODUCTS

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| | | | | | | |
|--------------|------|------|------|------|------|------|
| 26..... | ... | .3 | 4.0 | 15.6 | 29.7 | 50.4 |
| 28..... | ... | .1 | 0.3 | 4.8 | 15.6 | 79.2 |
| 29..... | ... | .7 | 3.8 | 8.5 | 20.3 | 66.7 |
| 31..... | ... | .1 | 0.4 | 1.1 | 9.1 | 89.3 |
| 32..... | ... | .2 | 1.3 | 3.1 | 8.2 | 87.2 |
| 34..... 0.3 | 0.7 | 2.5 | 8.8 | 16.4 | 11.1 | 60.2 |
| 35..... | ... | ... | 0.2 | 9.3 | 13.4 | 77.1 |
| 37..... | ... | ... | .1 | 6.1 | 9.7 | 84.1 |
| 43..... | ... | ... | .3 | 4.9 | 13.2 | 81.6 |
| Ave..... 0.0 | 0.1 | 0.3 | 2.0 | 7.7 | 14.5 | 75.1 |
| 3..... | ... | 0.2 | 0.9 | 3.1 | 10.7 | 85.1 |
| 4..... | ... | .1 | 1.3 | 4.1 | 12.4 | 82.1 |
| 12..... | 0.1 | .3 | 4.1 | 8.9 | 8.8 | 77.8 |
| 13..... | ... | .1 | 0.2 | 1.2 | 4.7 | 93.8 |
| 21..... | ... | .2 | 2.5 | 18.0 | 28.7 | 50.6 |
| 22..... | ... | .3 | 2.2 | 18.6 | 21.5 | 57.4 |
| 38..... | ... | ... | 0.2 | 2.6 | 7.7 | 89.5 |
| 41..... | ... | ... | 1.7 | 14.1 | 10.3 | 73.9 |
| Ave...* 0.0 | 0.0 | 0.1 | 1.6 | 8.8 | 13.1 | 76.3 |
| 5..... 0.1 | 0.1 | 0.1 | 0.9 | 3.3 | 10.8 | 84.7 |
| 16..... .1 | .1 | .1 | .2 | 0.8 | 6.4 | 92.3 |
| 23..... .1 | .1 | .2 | 1.7 | 14.8 | 21.9 | 61.2 |
| 27..... | ... | .2 | 0.9 | 2.8 | 17.0 | 79.1 |
| 33..... | ... | .3 | 1.5 | 4.8 | 28.7 | 64.7 |
| 36..... 0.1 | 0.4 | 2.3 | 13.5 | 16.8 | 9.6 | 57.4 |
| Ave..... .1 | .1 | 0.5 | 3.1 | 7.2 | 15.9 | 73.2 |
| 6..... 0.5 | 0.4 | 0.5 | 1.7 | 3.8 | 9.7 | 83.4 |
| 7..... .7 | .3 | .3 | 1.7 | 4.0 | 10.7 | 82.3 |
| 14..... .4 | .2 | .4 | 4.0 | 8.9 | 11.0 | 75.1 |
| 15..... .4 | .2 | .4 | 3.7 | 8.6 | 9.5 | 77.2 |
| 24..... .8 | .5 | .6 | 2.7 | 17.5 | 19.3 | 58.6 |
| 25..... .4 | .1 | .4 | 2.6 | 19.5 | 22.6 | 54.4 |
| 30..... .1 | .2 | 1.2 | 3.5 | 9.7 | 22.4 | 62.9 |
| 39..... 1.5 | 4.2 | 7.5 | 16.0 | 17.5 | 6.6 | 46.7 |
| 42..... 0.3 | 0.6 | 1.1 | 8.5 | 23.5 | 9.4 | 56.6 |
| Ave..... .6 | .8 | 1.4 | 4.9 | 12.6 | 13.5 | 66.4 |
| 9..... 0.1 | 8.9 | 10.9 | 18.0 | 25.4 | 16.7 | 20.0 |
| 18..... .8 | 21.2 | 21.6 | 10.8 | 11.4 | 3.8 | 30.4 |
| Ave..... .4 | 15.0 | 16.2 | 14.4 | 18.4 | 10.2 | 25.2 |
| 8..... 0.2 | 10.3 | 11.3 | 12.8 | 21.2 | 13.7 | 30.5 |
| 17..... 3.6 | 30.0 | 12.8 | 6.5 | 10.0 | 4.4 | 32.7 |
| 40..... 0.5 | 5.3 | 10.2 | 31.4 | 26.0 | 8.0 | 18.6 |
| Ave..... 1.4 | 15.2 | 11.4 | 16.9 | 19.1 | 8.7 | 27.3 |

TABLE 4

| Lab. No. | Compressive strength | Yield | | | Tensile strength | Normal consistency | Time of set |
|----------|----------------------|------------------------|-------------------------------------|-------------------------------|------------------|--------------------|-------------|
| | | Lbs. paste per cu. ft. | Lbs. dry material per cu. ft. paste | Lbs. set material per cu. ft. | | | |
| 1..... | 1460 | 106 | 64 | 76 | 254 | 66.1 | 21 |
| 2..... | 1315 | 107 | 64 | 75 | 775 | 66.9 | 21 |
| 10..... | 1700 | 113 | 77 | 88 | 333 | 46.6 | 12 |
| 11..... | 1570 | 107 | 66 | 79 | 270 | 56.2 | 7 |
| 19..... | 1105 | 101 | 58 | 68 | 244 | 73.2 | 11 |
| 20..... | 1060 | 102 | 58 | 68 | 220 | 75.0 | 19 |
| 26..... | 1550 | 113 | 74 | 82 | 413 | 53.0 | 14 |
| 28..... | 1580 | 112 | 72 | 81 | 387 | 56.0 | 22 |
| 29..... | 1956 | 114 | 77 | 89 | 357 | 48.0 | 16 |
| 31..... | 1935 | 107 | 68 | 78 | 394 | 58.0 | 8 |
| 32..... | 1875 | 110 | 72 | 83 | 444 | 51.8 | 12 |
| 34..... | 2200 | 114 | 76 | 85 | 437 | 50.0 | 13 |
| 35..... | 1630 | 111 | 69 | 79 | 280 | 60.2 | 9 |
| 37..... | 2285 | 116 | 75 | 83 | 299 | 51.5 | 8:00 |
| 43..... | 1720 | 92 | 57 | 78 | 270 | 61.0 | 9:00 |
| Ave..... | 1665 | 108 | 62 | 80 | 325 | 58.2 | 13:00 |
| 3..... | 1295 | 107 | 65 | 77 | 273 | 64.3 | 53:00 |
| 4..... | 925 | 105 | 63 | 74 | 236 | 66.0 | 11:56 |
| 12..... | 1420 | 111 | 76 | 87 | 290 | 46.2 | 2:54 |
| 13..... | 630 | 112 | 74 | 85 | 218 | 51.9 | 17:23 |
| 21..... | 1280 | 103 | 62 | 73 | 272 | 65.4 | 1.58 |
| 22..... | 1000 | 103 | 62 | 73 | 261 | 65.0 | 13:07 |
| 38..... | 145 | 93 | 50 | 54 | 37 | 85.5 | 1:00 |
| 41..... | 1400 | 120 | 83 | 87 | 129 | 44.6 | 5:37 |
| Ave..... | 1010 | 107 | 67 | 76 | 215 | 61.1 | 6:41 |
| 5..... | 555 | 104 | 63 | 73 | 182 | 65.7 | 14:15 |
| 16..... | 1100 | 110 | 73 | 80 | 254 | 51.2 | 25:24 |
| 23..... | 1030 | 106 | 66 | 75 | 269 | 61.0 | 13:09 |
| 27..... | 1730 | 107 | 69 | 81 | 379 | 55.5 | 6:34 |
| 33..... | 1475 | 115 | 75 | 83 | 400 | 53.3 | 8:50 |
| 36..... | 800 | 107 | 70 | 80 | 186 | 51.6 | 19:42 |
| Ave..... | 1115 | 108 | 69 | 79 | 278 | 56.4 | 14:39 |
| 6..... | 835 | 103 | 62 | 73 | 222 | 65.4 | 18:35 |
| 7..... | 670 | 103 | 62 | 74 | 195 | 66.3 | 6:17 |
| 14..... | 785 | 108 | 73 | 86 | 223 | 47.1 | 11:26 |
| 15..... | 885 | 109 | 75 | 87 | 259 | 45.7 | 6:20 |
| 24..... | 960 | 99 | 61 | 73 | 228 | 63.0 | 10:30 |
| 25..... | 910 | 101 | 60 | 71 | 232 | 67.4 | 12:24 |

| | | | | | | | |
|----------|------|-----|-----|-----|-----|------|------|
| 30..... | 1480 | 104 | 70 | 85 | 372 | 48.6 | 9:10 |
| 39..... | 275 | 115 | 75 | 78 | 73 | 53.0 | 3:10 |
| 42..... | 710 | 107 | 69 | 81 | 120 | 53.7 | 4:45 |
| Ave..... | 835 | 106 | 67 | 79 | 214 | 56.7 | 9:11 |
| 9..... | 195 | 129 | 101 | 108 | 52 | 27.0 | 2:19 |
| 18..... | 475 | 131 | 106 | 111 | 109 | 23.1 | 2:32 |
| Ave..... | 335 | 130 | 103 | 109 | 80 | 25.0 | 2:30 |
| 8..... | 200 | 126 | 98 | 104 | 53 | 29.0 | 1:52 |
| 17..... | 865 | 130 | 106 | 112 | 198 | 22.2 | 4:51 |
| 40..... | 180 | 120 | 95 | 103 | 37 | 25.8 | 3:27 |
| Ave..... | 415 | 125 | 100 | 106 | 96 | 25.7 | 3:23 |

6. Yield.—The above cylinder molds were weighed empty, and immediately after filling. The cylinders were weighed just before they were tested. The amount of dry material in a given volume of paste was calculated from the figure for normal con-

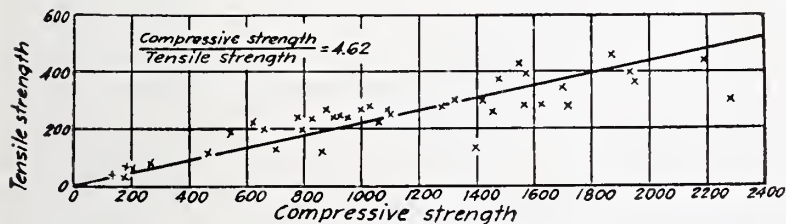


FIG. 1.—Compressive strength vs. tensile strength.

sistency. These data were used to calculate the weight per cubic foot of paste, the weight of dry material per cubic foot of paste, and the weight per cubic foot of set material.

7. Tensile Strength.—Three briquettes of the usual form were made of paste of normal consistency, stored in the same way as the compressive strength specimens, and tested when one week old. The results are expressed in pounds per square inch.

The results of all of these tests are given in the accompanying tables. Owing to the extremely confusing nomenclature, no attempt has been made to group the samples according to their trade names. They have been classified, instead, in accordance with their actual compositions.

Primarily, these data are intended to enable us to arrive at numerical values expressing the different properties of gypsum.

These values are to be used in writing specifications for the material. Incidentally, the data may also be used in an attempt to correlate the various properties. Certain efforts along this line are indicated in figures 1 and 2, showing the relations between

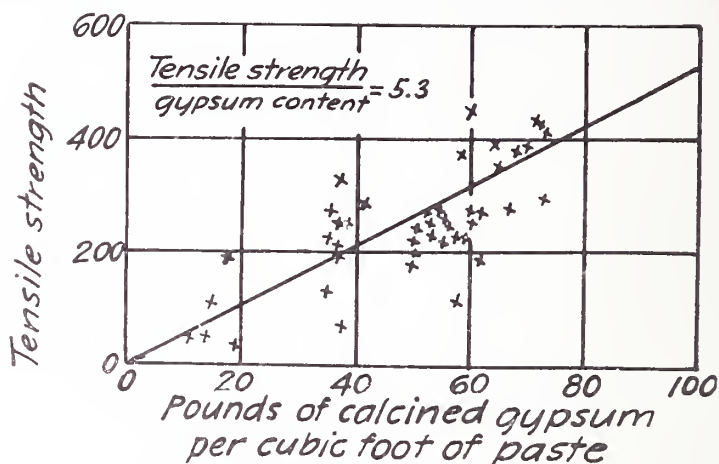


FIG. 2.—Tensile strength vs. gypsum content.

tensile strength and compressive strength, and tensile strength and gypsum content, respectively. Obviously the data permit and invite a great deal of this sort of calculation.

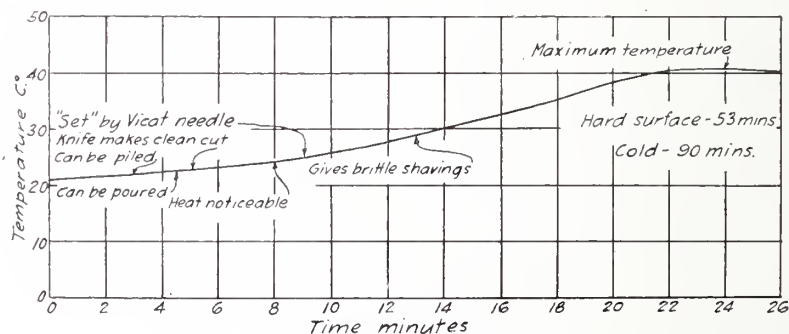


FIG. 3.—Time of set.

It seems that the present method of measuring time of set by means of the Vicat needle has been the subject of much criticism.

To get more information on this point, the times of set of ten samples were measured by means of the temperature rise, and by direct observation. The results for one of these samples are given in figure 3. All of these results confirm those previously¹ obtained: that the temperature rise method is fundamentally unsound, and is misleading. The Vicat needle is endorsed. It gives results which are definite, which can be checked, and which indicate the time during which gypsum may be worked without injury.

The use of the Southard viscosimeter to measure normal consistency has also been criticized. The results obtained by means of this instrument are probably accurate within 1 per cent, and can be readily checked by different observers. The machine is not portable, and its use is therefore confined to the laboratory. It was suggested that a cylinder mold two inches in diameter by four inches long could easily be carried in the pocket, and a "slump" test, using this mold, would measure consistency to a sufficient degree of accuracy. Accordingly, pastes of normal consistency (by the Southard viscosimeter) were made of 10 samples, and were tested by the slump method, using a two by four inch cylinder. It was found that the final diameter of the pat varied from $4\frac{1}{4}$ to $5\frac{1}{2}$ inches for the different samples. It would seem, therefore, that the slump method is hardly accurate enough for a standard method, although it will probably give satisfaction when used for plant control.

We wish to acknowledge our obligations to Mr. H. A. Bright for the analytical work, and to Mr. L. A. Balser for assistance in making physical measurements.

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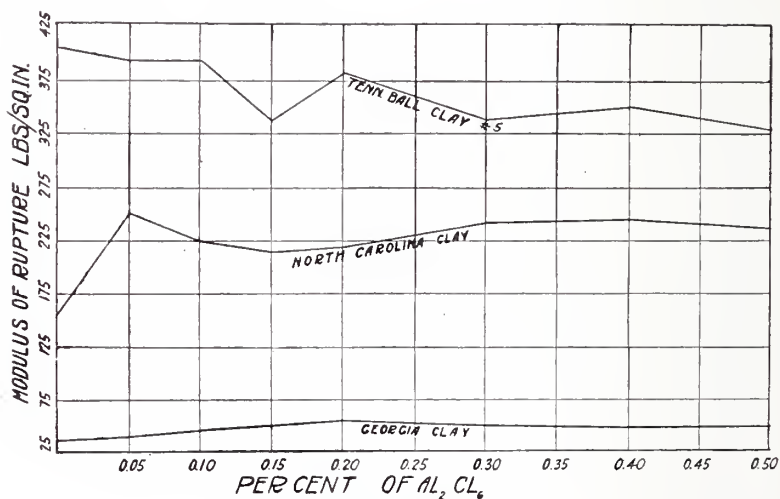
NOTICE—Further discussion of this subject is solicited. All communications should be sent to the Editor.

¹ Emley, "Time of Set of Calcined Gypsum," *Trans. Amer. Ceram. Soc.*, 19, p. 573 (1917).

THE EFFECT OF ALUMINUM CHLORIDE UPON CLAYS*

By H. P. REINECKER AND J. S. GEORGE, Washington, D. C.

In several potteries manufacturing vitreous table ware it has become a practice to add aluminum chloride to the body slip previous to the ball mill grinding. In all cases of this kind the composition contains but a comparatively small amount of ball clay and a predominating proportion of kaolin with respect to the total content of clay substance. The reason given for the use of aluminum chloride is that the working quality of the body is improved, presumably through the neutralization of any free alkali resulting from the wet grinding of the feldspar. There are others however who deny that any beneficial result arises from the use of the reagent.



EXPERIMENTAL

It was thought desirable therefore to conduct a few experiments along these lines in order to determine if possible what the effect of the chloride might be. The work was of a simple

* Received Feb. 27, 1920.

character and consisted merely in the addition of increasing amounts of aluminum chloride, varying from 0.05 to 0.5 per cent of the dry weight of three clays, the North Carolina and Georgia kaolins and Tennessee ball clay 5. The reagent was added to the clay in solution. In a supplementary series of experiments sufficient NH_4HO was used to precipitate the alumina as the hydroxide with, of course, the simultaneous formation of ammonium chloride. This was done for the purpose of ascertaining the difference in the effect produced between the aluminum chloride in solution and the colloidal hydroxide in the presence of NH_4Cl .

The clays thus treated were made into briquettes and bars and the water of plasticity, volume drying shrinkage and modulus of rupture in the dried state determined. The water of plasticity and shrinkage determinations are based on three specimens and the transverse strengths represent the average of six bars. The results of this work are compiled in the accompanying table:

TABLE I

| Al ₂ Cl ₆ added (NH ₄ HO) Per cent | Al ₂ Cl ₆ added with (NH ₄ HO) Per cent | Water of plasticity per cent of dry weight | | | Drying shrinkage in terms of dry vol. | | | Modulus of rup- ture in dry state, lbs. per sq. in. | | |
|--|--|---|-------|-------|--|-------|-------|---|-----|-------|
| | | N. C. | Ga. | Tenn. | N. C. | Ga. | Tenn. | N. C. | Ga. | Tenn. |
| 0.00 | .. | 44.63 | 39.84 | 47.32 | 29.2 | 18.9 | 34.30 | 160 | 37 | 404 |
| .05 | .. | 40.17 | 40.10 | 45.33 | 23.6 | 18.7 | 33.05 | 251 | 41 | 393 |
| .10 | .. | 40.64 | 39.50 | 48.07 | 25.6 | 18.3 | 35.60 | 225 | 46 | 393 |
| .15 | .. | 42.05 | 38.35 | 49.33 | 26.7 | 18.2 | 36.40 | 214 | 51 | 337 |
| .20 | .. | 41.77 | 38.20 | 49.83 | 27.1 | 17.65 | 36.70 | 219 | 56 | 382 |
| .30 | .. | 42.69 | 37.80 | 49.01 | 27.3 | 17.55 | 34.75 | 244 | 57 | 338 |
| .4 | .. | 43.20 | 39.36 | 49.03 | 29.0 | 19.85 | 34.10 | 249 | 48 | 353 |
| .5 | .. | 42.35 | 38.29 | 49.05 | 28.9 | 18.35 | 33.80 | 239 | 49 | 329 |
| .. | 0.05 | 42.97 | 38.59 | 48.98 | 27.05 | 16.20 | 35.20 | 142 | 57 | 329 |
| .. | .10 | 42.03 | 39.12 | 48.40 | 25.90 | 17.0 | 34.70 | 151 | 67 | 413 |
| .. | .15 | 43.37 | 39.48 | 49.78 | 27.4 | 17.05 | 34.85 | 160 | 65 | 333 |
| .. | .20 | 40.62 | 38.74 | 50.06 | 25.3 | 16.60 | 35.15 | 167 | 57 | 367 |
| .. | .30 | 43.41 | 42.61 | 51.2 | 27.5 | 20.3 | 34.80 | 172 | 61 | 304 |
| .. | .40 | 44.16 | 41.77 | 54.79 | 28.7 | 19.45 | 37.30 | 182 | 70 | 236 |
| .. | .50 | 43.05 | 42.28 | 53.73 | 27.85 | 19.75 | 35.80 | 213 | 62 | 280 |

Discussion of Results

It is at once apparent from the results obtained that the effect of aluminum chloride shows phases of maxima and minima as found in the previous work of Bleininger and Fulton, of Back, Schurecht and others.

It appears that additions of aluminum chloride, without and with the use of ammonia, do not bring about decided changes in the amounts of water of plasticity, the greatest change being observed with 0.4 and 0.5 per cent of Al_2Cl_6 plus NH_4HO .

The addition of aluminum chloride alone reduced the drying shrinkage of the North Carolina and the Georgia kaolin, though an exception is noted in the case of the latter with 0.4 per cent. The Tennessee ball clay shows alternate phases of reduced and increased shrinkage, a condition typical of all systems of this kind. Practically the same statements apply to the use of Al_2Cl_6 plus ammonia.

The only clay whose strength in the dry state is markedly improved by the addition of Al_2Cl_6 alone is the North Carolina kaolin. A much less marked gain in strength is observed with the Georgia kaolin and a decided decrease in strength by the Tennessee ball clay. The further addition of NH_4HO practically neutralizes the gain due to the use of Al_2Cl_6 in North Carolina kaolin except when as much as 0.5 per cent is used. The ammonical condition on the other hand increased the gain in strength of the Georgia kaolin but brought about no marked change over the use of Al_2Cl_6 alone.

It would seem then that the use of aluminum chloride increases the mechanical strength of the primary kaolin exercising but a much less marked influence in the same direction on the secondary kaolin and decreasing the strength of the ball clay. The effects observed are evidently due to the salt in solution, and the acidity caused by the dissociation of the Al_2Cl_6 . With larger amounts of aluminum hydroxide present a gain in strength may be brought about by the colloidal precipitate formed.

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NOTICE—*Further discussion of this subject is solicited. All communications should be sent to the Editor.*

THE USE OF AMERICAN RAW MATERIALS IN THE MANUFACTURE OF WHITEWARE POTTERY

BY A. V. BLEININGER AND W. W. McDANEL

DISCUSSION

Mr. C. Merts Franzheim.—The article appearing in the February issue of the magazine on "The use of American raw materials in the manufacture of whiteware pottery," giving in detail the results of extensive experiments by Mr. A. V. Bleininger and W. W. McDanel has made a solid contribution to the subject of the use of American clays. I should like to answer this article in brief.

The writer has for many years been interested in various connections in the development of American clay mines, has visited many, and has been instrumental in aiding in the production and actual marketing of the output, having in mind a product which would prove satisfactory to the potting trade. I have worked along with the development of mine and mill in order to make sure that the clay was properly mined, washed and prepared and maintained up to quality.

In spite of all instructions and counsel regarding the necessity of maintaining a standard of selection and a standard of washing, and sticking to it, in no case have I ever found where this was continuously followed. On the other hand the superintendent or manager of the plant would do what he thought wisest or best at the particular time a problem would arise, regardless of the ultimate outcome. These managers or superintendents are not as a rule acquainted with how the clay is used nor are they familiar with pottery practice.

One plant I have in mind at this time had all the necessary capital and had built one of the finest plants in the country and were actually in a position to turn out a very fine product. The mill was well equipped and well supplied with the proper facilities and knowledge to do good work. Careful instructions were given regarding the necessity of the selection of the clay, the milling

and mining, and every detail. A cut and dried program was established so that the very best results could be obtained in the shortest period of time. The work should have progressed as planned. After one month I returned to the mine to find the superintendent had rearranged his own program and was doing things as he thought they should be done, but which proved to be the reverse of good practice. In other words, he used his judgment in the selection of the clays and in the washing, and was turning out a product far from satisfactory, and which would not be, nor ever could be, satisfactory to the potter.

Many instances of such ill-advised work could be cited. In some of the American mines the endeavor seems to be to work into the clay as much refuse material as possible, thinking perhaps that it will not be noticed.

The American miner is optimistic—far more so than he should be, and then adds carelessness to his work not intentionally perhaps, but because he does not understand clay values, or is ignorant of the principles of true applied carefulness, or is blind to his own faults. It is not possible, and never will be possible, to turn out any good American clay for white ware on the working basis that has existed in the clay mining trade of this country in the past. It seems impossible to make the miner realize the necessity of most careful selection to say nothing of the delicate methods of handling during the washing process. And no American product is going to succeed until these things are more fully appreciated.

Had we in America today exactly the same type of primary clay deposit that they have in England, we ourselves could not compete with English quality if the same apparently thoughtless and careless methods of mining and washing were pursued as now exist.

There are combinations of various American clays which have been proven to yield satisfactory American ceramic products, but with few exceptions the potteries have lacked confidence in the ability of the miner to produce his product carefully, conscientiously, and above all, uniformly.

CERAMIC ABSTRACTS¹

General

A promising tunnel oven. STAFF ARTICLE. *Pottery Gaz.*, **45**, 1208-11 (1920).—The Marlow oven takes the form of a long, brick-built tunnel which can be so adjusted in length, height, and width to suit the particular local circumstances of any factory, large or small, at which it may be decided to install it. One operating at the Patent Tile Works, Stoke, Eng. is 150 ft. long, 7 ft. 6 in. from floor to crown and 8 ft. 6 in. at the base. Through the tunnel runs a railway along which the ware to be fired is passed. The train of trucks are driven through the tunnel by a motor which drives a reduction gear. One truck is drawn every hr. and the tunnel holds in all 30 trucks, which is equal to 30 hrs. from the time of feeding to the time of drawing. Eight trucks are filled and 8 trucks drawn by each shift of workers. Tile were fired in the kiln described but most any class of pottery may be fired in this kiln. Although the use of saggars has not been eliminated, they are retained as a convenience rather than a necessity. They have proved handy for lifting tile on and off the trucks. Each sagger contains 40 tiles and it is possible to place 33 saggars on each truck, which is equal to about 25 sq. yds. of tile per hr.—day and night. The wear on saggars in the tunnel kilns is comparatively small since the saggars support only a small load as compared with those used in the intermittent kiln where the bungs are often 17 high. Saggars were not used in one case in burning domestic ware, and the ware was perfectly fired without showing signs of sulphuring. This is due to the fact that perfect combustion is obtained by a special method of firing. The system is that of direct gas firing by a method of superheating, in which both gas and air required are heated to a high temp. before combustion. The air is brought in at the ingoing end of tunnel, taken through the firing zone and afterwards brought back and used in the combustion chamber. The three essentials for gas firing are (1) the producer shall be so constructed as to give a regular flow of gas, (2) the recuperation or superheating of the air shall be of such a nature that the air comes into contact with the gas at a temp. very nearly as high as that of the firing zone, and (3) the exhaust which really governs the whole procedure, must be so arranged as to exert a uniformly distributed pull, capable of drawing from all parts of the oven at the same speed. The temps. of given sections of the tunnel can be raised or lowered at will by merely opening or closing of dampers and regulating the influx of gas and air respectively. It has been possible within a space of 9 hrs.

¹ The abbreviation (C. A.) at the end of an abstract indicates that the abstract was secured from the Editor of Chemical Abstracts by coöperative agreement.

to fire successively 3 trucks of ware to a temp. of 1165°C ; 3 trucks to 1040°C , reverting during the last 3 hrs. to the previous temp. The exhaust by means of which the sulphurous vapors are removed is remarkable. The exhaust is constructed at the level at which the heated gases are required to be drawn. The arrangement consists of a system of pipes, through which an even pull is exerted by a fan placed in the hovel of a disused oven. Sections of the exhaust if necessary, can be placed at different parts of the tunnel, so that by means of a damper fixed in an overhead flue, any of the exhaust sections can be used separately, an arrangement which makes it possible to lengthen or shorten the soaking zone when required. The exhaust is so perfect that a chimney stack is not necessary.

H. G. SCHURECHT.

Pyrites in clay. J. SCOTT. *Brit. Clayworker*, 29, 167-8 (1920).—Common pyrites frequently contains small quantities of copper, arsenic, tin and other metals, the existence of which complicates their chem. reaction with other materials. In firing brick containing pyrites, the S is eliminated and changed to H_2SO_3 . The remaining Fe fuses to black lumps. Pyrites is more likely to be a nuisance than a benefit to clays.

H. G. SCHURECHT.

The binary system, âkermanite-gehlenite. J. B. FERGUSON AND A. F. BUDDINGTON. *Amer. Journ. Sci.*, (4) 50, 131-40 (1920).—The binary system âkermanite ($2\text{CaO}.\text{MgO}.2\text{SiO}_2$)-gehlenite ($2\text{CaO}.\text{Al}_2\text{O}_3.\text{SiO}_2$) was studied by the quenching method and the solidus and liquidus curves determined. The system forms a complete series of solid solutions with a minimum melting point about 70° below the melting point of âkermanite, the component of lower melting point, at a composition of about 74 per cent âkermanite and 26 per cent gehlenite.

The densities of crystals and glasses of âkermanite, gehlenite, and several intermediate mixtures were determined and found to confirm the isomorphous character of the system. âkermanite was found to show the unusual feature of its glass having a greater density than the corresponding crystals at 25°C . This peculiar character is checked by the indices of refraction, respectively for glass and crystal, the index of refraction of the glass being greater than the maximum index of the crystal.

The optical characters of the crystals are a continuous function of the composition. âkermanite is positive in its optical characters and gehlenite is negative. Crystals of certain intermediate compositions are isotropic for light of a definite wave length and constitute a transition phase between positive and negative crystals.

Vogt has discussed the relations of âkermanite and gehlenite as interpreted from a study of slags. He concluded that they mix to form an isomorphous series, and found that the birefringence of intermediate mixtures decreases to 0. However, the formulas assumed by Vogt for âkermanite and gehlenite differ from those used by the authors, and most of his materials contained iron, manganese, soda, or other impurities, so that the data he obtained are the result of more complex mixtures than the system discussed in this article.

ROBERT B. SOSMAN.

New facts about surface friction. CH. TERZAGHI. *Phys. Rev.*, 16, 54-61 (1920).—These investigations are preliminary to the study of the physical properties of clays. A study was made of the smooth glass plates in order to determine the laws governing the frictional forces. The frictional resistances are due to the existence of microscopic particles that deposit themselves upon the rubbing surfaces and not into the shearing strength of air or water. Evaporation of a drop of water placed between two plates ceased when the thickness of the film was about 100 mm, which indicates that molecules of a solid exert force over a distance of about 50 mm. Viscosity, shear and tensile strength are involved in the action of such thin films of water. The author uses these results to explain the facts (1) that clay layers are impermeable unless the heat exceeds a certain minimum; (2) that the water contents of clays do not drop below certain limits. T. concludes that the ordinary loss of friction of rest apply only where contact between the rubbing surfaces must be enforced by outside pressure. When two even surfaces are in contact the explanation of the cause of friction is not so simple on account of the presence of small particles on the surface.

A. J. LAMBERT.

Magnesite in New Mexico. ANON. *Min. Sci. Press*, p. 422, (1920); *Eng. Min. Jour.*, 110, 673.—A small deposit of magnesite, having no commercial value, and lying 30 miles north of Lordsburg, N. Mex., was recently examined by R. W. Stone of the U. S. G. S.

D. D. SMYTHE.

Purifying clays by electrical osmosis. J. S. HIGHFIELD, DR. W. R. ORMANDY AND D. NORTHALL-LAURIE. *Mining Magazine*, 23, 113-4.—Gives a general discussion of electrical osmosis and then proceeds to discuss the separation of pyrite, silica, and mica from clay by this method. The process has a wide range of application to different varieties of clays, the cost varying likewise.

D. D. SMYTHE.

Talc in South Africa. T. G. TREVOR. *Mining Magazine*, 23, 185-6.—The Scotia talc mine has recently been opened in the Barberton District, South Africa. The talc lies in a series of beds 400 feet thick. Development work has proved that there is enough talc to warrant the establishment of a permanent industry, and that the talc can be mined and hoisted for a few shillings a ton. A mill capable of handling 500 tons a month has been installed and is now in operation.

D. D. SMYTHE.

Science of powdered-fuel combustion. JOSEPH F. SHADGEN. *Iron Age*, 106, 457-61 (1920); cf. *C. A.*, 14, 1028.—A preliminary general discussion of heat is accompanied by tables illustrative of (1) vol. of air required for the complete combustion of a given coal; (2) influence of excess air on analyses of waste gases; (3) theoretical temp. of combustion with various air quantities, and (4) influence of preheated air. The effects of moisture and of pulverization are sketched. While formerly an av. of 25 per cent to 35 per cent volatile matter was usually recommended, today, as a result of improved design,

all grades of solid fuel—lignite, sub-bituminous, anthracite culm, or coke breeze—are successfully burned in powder form. The coking quality of a coal is practically without significance. Ash, however, presents a considerable problem. The effort expended in grinding and transporting it is lost; the heat absorbed to raise its temp. is lost; very serious accumulations may result; dangers of slags and fluxes that destroy walls and roof arches are introduced. The ash should be sepd. before burning and the attempt to eliminate it should be made after pulverization. With regard to furnaces necessitating Siemens regenerative chambers, it is thought that an ash content of 1 per cent to 2 per cent will reduce all troubles to an acceptable practical minimum. [C. A.]

PATENTS

Method and means for firing tunnel-kilns. JOHN B. OWENS. U. S. 1,355,906, Oct. 19, 1920. A tunnel kiln having a combustion chamber communicating at its side with the interior of the tunnel and provided with means for deflecting from the chamber into the tunnel the heat and products of combustion developed within the chamber, and means for firing the combustion chamber in the direction of its length.

Firing means for tunnel-kilns. JOHN B. OWENS. U. S. 1,356,397, Oct. 19, 1920. A tunnel kiln having a multiple firing or burning zone, with combustion chambers communicating with the firing zone at different points of the combustion chambers in a direction other than toward their communication with the firing zone. The chambers have means to directly and initially deliver the heat and products of combustion derived from firing onto the lower portions of the ware in the tunnel. The chambers maintain the multiple firing zone for the purpose of subjecting the goods or ware to a relatively long "soaking" heat at the temperatures necessary to burn the same. The kiln is provided with draft means adapted to cause the heat and products of combustion to directly flow from the chambers into the tunnel and in the same direction through the multiple firing zone after first striking the lower portions of the ware.

Tunnel-kiln. PHILIP DRESSLER. U. S. 1,354,541, Oct. 5, 1920. A tunnel with combustion chambers arranged on each side of the interior of the inclosing structure, the combustion chambers each divided into two sections connected by a sleeve which permits relative movement between such sections, together with means for introducing gas and highly heated air into one section of each chamber and projecting it longitudinally into the adjacent section of the chamber.

Continuous tunnel-kiln. PAUL A. MEEHAN. U. S. 1,355,407, Oct. 12, 1920. A continuous kiln of the tunnel type, with an elongated kiln chamber comprising two sections meeting at an angle and a turntable within the kiln chamber at the junction of the sections for receiving a goods carrying car approaching the table from one section and rotating it into alignment with the other section.

Multiplex tunnel kiln. JOHN B. OWENS. U. S. 1,356,398, Oct. 19, 1920. Describes a car tunnel kiln having a closed partition rising between the car platform and extending lengthwise through the kiln between the sets of tracks, the walls of the kiln being imperforate where they face the partition. Means are provided for sealing those parts of the tunnel which are below the cars from those parts which are above the cars, whereby the partition and the ware or clay products on the cars define a longitudinal flue in the kiln compelling the passage of the heat and products or combustion lengthwise through the tunnel of the kiln.

Method of firing tunnel-kilns and convertible furnace therefor. JOHN B. OWENS. U. S. 1,356,396, Oct. 19, 1920. A kiln in which the ware is burned, having a combustion chamber opening into the burning chamber, and means for directing heat into the combustion chamber from any one of a plurality of independent sources of fuel differing in kind and extraneous to the combustion chamber.
C. M. SAEGER, JR.

Refractories

Refractories for electric furnaces. ANON. *Chem. Met. Eng.*, **23**, 769-70. —Report of symposium on refractories for electric furnaces held by the Electric Furnace Association in Columbus on October 6, 1920. The ideal refractory for electric furnaces should have a melting point higher than 1750° C; should be highly resistant to sudden temperature variation so as to permit intermittent operation; should be constant in volume at high temperatures; should resist the scar of slag and should withstand the action of fumes, hot gases and molten metals; should be a poor conductor of electricity and should have considerable mechanical strength at high temperatures. When fire clay brick are used in electric furnace side walls, unless the walls are very thin and radiate heat very rapidly, the inner surfaces melt down very quickly or soften and absorb quantities of slag and metal from the bath. Silica brick, up to the present, have given best service in roof arches. They melt at about the same temperature as good fire clay brick but retain their shape and much of their strength to a high temperature. They must be heated or cooled at a very low rate and thus are not suitable for intermittently operated furnaces. Magnesite brick are most commonly used for basic linings. Carborundum brick have been used to some extent for door jams and roofs. Among possible refractory materials to be considered are alundum, sillimanite mixtures, magnesia spinel, zirconium oxide, zirconium silicate, and fused magnesia.
A. J. LAMBERT.

Refractory materials for chemical purposes. A. B. SEARLE. *Chem. Age (London)*, **2**, 684-50; **3**, 123-4 (1920).—Resistance to pressure at high temperatures can be secured by using compositions that are essentially one chemical compound. Mixtures of compounds soften below their ultimate melting point due to the formation of eutectics. Vitrification gives resistance to corrosion and abrasion, but usually increases tendency to spall. For re-

sistance to corrosion by liquids and gases, an impervious structure is more important than chemical composition. Numerous large scale tests have shown that silica and fire clay brick may be used advantageously in steel furnaces in which a highly basic (calcareous) slag is produced provided that the bricks are sufficiently impervious to present a minimum area to the corrosive action of the slag. If porous bricks are used, rapid corrosion occurs. The use of magnesite brick in contact with acid slags is less satisfactory because the texture of the bricks is coarse and more favorable to chemical corrosion. The action of acid slags on a mass of fused magnesia is scarcely appreciable, but if the magnesia is reduced to a coarse powder it is rapidly dissolved by the slag.

E. T. RODGERS.

Preparation of magnesium oxide. ANON. Bur. Standards Tech. News, *Bull.* 43 (1920).—Magnesium oxide is packed about a small carbon rod between two large carbon electrodes set in the end of a box-like concrete shell lined with zircite. The electric current first heats the small carbon rod to a temperature which fuses the magnesium oxide with which it is surrounded. This fused magnesium oxide then has greater conductivity and the cross-section of this core of the fused material gradually increases to the end of the run. A run in one small furnace takes about 30 minutes and a fused core of about 15 to 20 lbs. of pure magnesium oxide is produced.

E. T. R.

A new method for the determination of zirconium. MELVIN M. SMITH AND C. JONES. *J. Am. Chem. Soc.*, 42, 1764-70(1920).—The only reliable method, viz., "cupferron," for the quantitative determination of Zr is impracticable commercially because of its cost and its lack of simplicity with other elements present. The new method is based on the precipitation of basic selenite by H_2SeO_3 in acid (HCl) solution. Comparative tests by the cupferron method with known solutions showed the new method to be thoroughly accurate, the greatest difference between the two being 0.3 per cent. Free H_2SO_4 should not be present and the solution should not contain over 7 per cent concentrated HCl. The selenite precipitate is soluble in 10 per cent free acid, but precipitation from 7 per cent HCl gives no loss of Zr. Detailed procedure is given for precipitation of H_2SeO_3 and for separation of Zr from Al, Fe, Ti, H_3PO_4 and the rare earths. To determine Zr in ore fuse it with 10 wt. of KHF_2 to a clear liquid, treat with 1 : 1 H_2SO_4 and heat to fuming. Boil the residue with H_2O and dilute. Precipitate with NH_4OH (NH_4Cl present), wash the precipitate, dissolve in HCl, dilute, and precipitate with H_2SeO_3 . Filter off the insoluble basic selenite, wash with 3 per cent HCl, and ignite to ZrO_2 .

[C. A.]

PATENTS

Combination of matter for fire-bricks and refractory linings. ARTHUR F. QUIN. U. S. 1,355,689, Oct. 12, 1920. A refractory composition comprising mica, asbestos and salt ground and mixed.

Refractory material. JOHN A. OHMAN. U. S. 1,356,939, Oct. 26, 1920. A non-recrystallized refractory material for heat resisting articles comprising silicon carbide and crystalline graphite.

C. M. SAEGER, JR.

Glass

"The influence of strain on the properties of optical glass." J. BERNDT. *Zeits. fur Instknde.*, Jan., 1920, *et seq.*—(1) Annealed sections cut from plate glass possessed a somewhat higher value for compression and tensile strength test than unannealed rods. Higher values were obtained for annealed material if the test pieces in their final condition are made strain free. The cross bending strength is greater for strained pieces. It is essential to carry out experiments on well annealed pieces because deviations up to 25 per cent may be caused by strain. The assumption of Schott regarding a compression layer formed by air cooling is only justified for articles not to be subjected to further working. Greater strength results from good annealing if the compression layer is to be cut through or if pieces are to be subjected to cutting or grinding, as in optical work. The scratch test shows the same value for strained and for annealed glass. (2) *The influence of strain on the modulus of elasticity.* Quincke found that for a fiber of flint glass the modulus of elasticity increased about twice on standing for six months and that it was four times smaller in strained pieces. The values of Winkelmann and Schott are: Strained 754,300 Kg/mm² annealed 750,900 Kg/mm², Ludwig found: strained 700,000, annealed 600,000. For a boro-silicate crown, strained 814,600, annealed 755,700 showing an increase of 7.8 per cent. Annealing always causes an increase of about 8 per cent. Quincke's result is attributed to his method of observation. Kundt's figures were used. (3) *Refraction and density.* On density no quantitative references were found except these of Schott who stated that the removal of strain was accompanied by a decrease in volume and an increase in density.

| Refractive Index. J. O. Reed. The index was increased on annealing. | | | |
|---|------------------|-------|----------------------------|
| Designation of glass | N _D . | Temp. | Changes in 5th deci. place |
| | | o | |
| S 57 | 1.96243 | 299 | —81 |
| S 163 | 1.89033 | 364 | —17 |
| O 165 | 0.75448 | 408 | —14 |
| O 211 | 1.57270 | 406 | o |
| O 527 | 1.57170 | 406 | o |
| O 154 | 1.57089 | 452 | —93 |
| O 1299 | 1.60982 | 404 | +1 |
| O 1805 | 1.51754 | 411 | o |
| O 1805 | 1.51828 | ... | —27 |

Reed: glass from optical pots differ as much as 15 to 93 units in 5th decimal place. Samples from the same plate show 25 in 5th place. Samples from same melt but not from same plate show two in 3rd place, but in these experiments part of their difference can be attributed to strain. In the same prism influences of inhomogeneity are eliminated and here differences of 3 units in 3rd place can be caused by strain. Strained 6385, annealed 6438,

difference 0.8 per cent. (4) *Specific refractivity*. Certain types of glasses are almost in agreement with Newton's formulas $(n^2 - 1)/d$. $(n - 1)/d$ is correct to about 0.1 per cent. The Lorenz-Lorentz formula is correct to plus 0.2 per cent to -1.8 per cent, Newton's to -0.3 per cent plus 0.07 per cent. (5) *Influence of strain on the expansion of optical glasses*. Schott's observation on short cylinders gave a variation of 5 per cent to 15 per cent on annealing. Berndt cites one glass in which the expansion increased 17 per cent in the strained condition. A decrease of 5 per cent in barium crown glass was observed on annealing. (6) *The applicability of Hooke's law to glass*. The cross section was 2 to 5 mm. and the sample was loaded to fracture. Hooke's law held up to the point of fracture within 1 per cent. Permanent deformation was not shown in the short interval of time used. *Summary*. The strength of plate glass: Compression strength, 12400 average, 13800 maximum, Kg/Cm²; tensile strength, 710 average, 760 maximum; transverse strength, 920 average, 980 maximum. Strength of boro-silicate, 516/680, annealed. Compression strength, 18,100 ave., 20,900 max.; tensile strength, 690 ave., 870 max.; transverse strength, 1080 ave., 1120 max.; scratching hardness, 55.3; modulus of elasticity, 814,600. By strong strains the density of glass is decreased by 0.8 per cent and the refractive index by 2.2 per cent. Therefore, the γ value is constant to less than 0.1 per cent. If a compression layer is present the expansion coefficient increases with increasing temperature. The forces exerted by strain give value of about 2000 Kg/Cm² which effects a diminution in length of maximum of 0.3 mm. per 100 meters of length. Generally an increase of density takes place of about 2 in. 2nd decimal on annealing and the refractive index changes by about 3 in 3rd place.

WM. M. CLARK.

The absorption of heat in glass. A. Q. TOOL AND C. G. EICHLIN. *Journ. Opt. Soc. Am.* 4, 340-63 (1920).—Glass, on being heated, exhibits within a definite and narrow temperature range a marked increase in heat absorption. This may be caused by one or more types of molecular aggregates, which may have a crystalline structure. Chilling or annealing glass produces the effect that should be expected if the absorption of heat on heating and its evolution on cooling are due to the formation and dissolution of some such crystalline structure or other molecular aggregate. It is possible that certain methods of cooling or treatment may cause structural inhomogeneity in glass through the non-uniform formation of these aggregates.

E. T. RODGERS.

Cause of blisters in glassware. T. D. LONG. *Glassworker*, 39, 18 (1920).—Blisters are caused by vacuum due to cooling too long. An experiment is described to prove this. A gathered piece held in a stream of compressed air will form blisters on the inside. On heating in a glory hole they will disappear and will not reform on cooling if the cooling is properly done.

R. J. M.

Glass container research. work J. M. HAMMER. *Glassworker*, 40, 11 (1920).—A general description of the work being done by Dr. A. W. Bitting in the laboratory of the Glass Container Association of America.

R. J. M.

Glass colors. *Schnurpfeil's Review for Glass Works*, 4, 685 (1920).—The normal color for the ordinary coloring oxides in various kinds of glass is given:

| Metal oxide | Lead glass | Potash glass | Soda glass |
|--------------------------------------|-----------------|------------------|---------------------|
| Silver oxide | ..... | Yellow or orange | Yellow or orange |
| Chrome oxide | Greenish red | Greenish yellow | Grass green |
| Cobalt oxide | Pure blue | Blue | Bluish violet |
| Copper oxide (red oxide) | Blood red | Purple | Purple (yellowish) |
| Copper oxide | Green | Sky blue | Sky blue (greenish) |
| Ferrous oxide | Greenish yellow | Bluish green | Bluish green |
| Iron oxide | Greenish yellow | Bottle green | Bottle green |
| Manganese oxide | Amethyst | Bluish violet | Reddish violet |
| Nickel oxide | Bluish violet | Amethyst | Yellowish violet |
| Purple precipitate of cassius (gold) | Red or rose | Red or rose | Reddish blue |
| Uranium oxide | Topaz | Siskin yellow | Greenish yellow |
| Sulphur, carbon | Black | Golden yellow | Pale yellow |
| Antimony oxide | Orange (opaque) | ..... | ..... |
| Selenium | ..... | Pink | Salmon color |
| Tin oxide | Enamel white | White | White |

R. J. MONTGOMRY.

Alabaster glasses using talcum. *Schnurpfeil's Review for Glass Works*, 4, 685 (1920).—No. 1—Sand 100, soda ash 35.5, lime 10, saltpetre 5, talcum 16.5, fluorspar 3. No. 2—Sand 100, soda ash 38.5, lime 8, talcum 14.5, fluorspar 4, arsenic 0.5. No. 3—Sand 100, soda ash 36, lime 8, talcum 20, saltpetre 8. Talcum (soapstone, steatite) is used for opacifying glasses. It contains silicate of magnesia and makes the glass refractory. R. J. M.

Composition of chemical glass. *Schnurpfeil's Review for Glass Works*, 4, 687 (1920).—Sand 100, soda ash 35, lime 18, borax, 4, alumina 8, manganese 0.25, arsenic 0.25. R. J. MONTGOMERY.

Composition of Bavarian plate glass. *Schnurpfeil's Review for Glass Works*, 4, 687 (1920).—Blown plate glass: No. 1—white sand 1000, potash 175, soda ash 180, lime 250, manganese 2, arsenic 2; No. 2—white sand 1000, soda ash 340, lime 260, saltpetre 10, arsenic 5, manganese 1. R. J. M.

Composition of cheap watch glass. *Schnurpfeil's Review for Glass Works*, 4, 687 (1920).—Sand 100, soda ash 33, lime 10, barytes 5, lead 3, saltpetre 2, arsenic 0.5, manganese 0.2, nickel oxide 0.001. R. J. MONTGOMERY.

A note on the annealing of optical glass. L. H. ADAMS AND E. D. WILLAMSON. *J. Optical Soc. Amer.*, 4, 213-23 (1920).—The old method of annealing optical glass consisted of heating the glass rather slowly to a maximum temperature and then cooling it gradually from that temperature

The authors recommend a new method in which the glass is heated very rapidly to a rather low annealing temperature, is held for some hours at that temperature and is then cooled at a rapidly increasing rate. A. J. LAMBERT.

A method for determining the annealing temperature of glass. J. T. LITTLETON AND E. H. ROBERTS. *J. Optical Amer.*, 4, 224-9(1920).—A glass cane, ten centimeters long and four to five millimeters in diameter, was sealed between two larger pieces of cane of one centimeter diameter, the ends of which were held in chucks. One chuck was centered on the axis of a ball-bearing pulley wheel, the other to a universal joint. The temperature of the furnace in which the glass was heated was raised at the rate of one or two degrees per minute. This rate could probably be increased. The pulley wheel was loaded at the rim so that a shearing stress of 4 kg/mm² was given to the glass. After the rod was inserted in the furnace the load was applied and the position noted of a spot of light reflected from a concave mirror attached to the axis of the wheel and focussed on a scale two meter distant. The rate of motion of this spot was taken as a measure of the fluidity of the glass. The recording of the position of this spot and the temperature of the furnace at various intervals gave values from which a viscosity curve was obtained. This determined the rate of rotation at 550° C for standard glass to be 16 cm per minute or an angular rotation of 5° 32' per minute. Hence to obtain the annealing temperature of any glass, the above experiment is repeated on the glass and the temperature which gives a scale deflection of sixteen centimeters per minute is the annealing temperature of the glass. The slope of the curve obtained by plotting the logarithm of the fluidity against the temperature is a measure of the rate of viscosity change for the deflection is determined as above, using the same units and rods of the same dimensions, gives a temperature at which the glass takes on very little permanent strain when cooled at any ordinary rate. At this temperature the glass anneals in about sixteen hours. The maximum temperature to which it is safe to heat a glass may be determined by practical tests on the standard glass in the form of ware commonly used. Having determined the maximum temperature, the point on the fluidity curve at that temperature gives a measure of the maximum allowable fluidity. Therefore any glass of a fluidity equal to this standard is at the maximum safe temperature. Using these methods the following min. and max. values were obtained for various Corning glasses:

| Glass type | Annealing point ° C | Straining point ° C |
|--------------------|------------------------|------------------------|
| Borosilicates..... | 518 | 470 |
| | 550 | 503 |
| Limes..... | 472 | 412 |
| | 523 | 472 |
| Leads..... | 419 | 364 |
| | 451 | 382 |

A. J. LAMBERT.

The melting of colored glasses. ANON. *Glasindustrie*, **31**, 209-10 (1920).—An alkali mix is the usual basis of colored glasses. The chemical composition, the nature of the coloring oxides and the furnace operation must all be carefully watched. The yellows are very difficult to produce. Twenty formulas for yellow glass are given, 10 for blue, 32 for green, 2 for gold-ruby, 2 for copper-ruby, 2 for gray, 2 for black and 2 for brown. C. H. KERR.

Ultramarine blue. DR. ING SPRINGER. *Die Glashutte*, No. **33**, Aug. (1920).—Ultramarine blue is an aluminous silicate containing sulphur, easily dissociated with simultaneous disappearance of color so that it produces in glass fusions a yellow or brownish color instead of blue. Experiment was tried of adding 5 parts ultramarine blue to 100 parts sand in a high soda-lime-glass batch in a laboratory furnace. Shortly after heating at a low temperature the blue color of the frit disappeared and same became light yellow; then when heated strongly to fusion the yellow color disappeared and the glass became of a light bluish tinge so that a partial reformation of ultramarine is conceivable as has been previously observed (unless the high iron content may have been responsible for the color). A second experiment was tried adding 10 parts ultramarine to 100 parts sand and after fusion resulted in a strong yellowish red, sulphur-ruby colored glass of very beautiful and evenly distributed characteristics. It is possible that ultramarine is well adapted to the formation of orange and sulphur rubies. WM. M. CLARK.

Optical glass and its future as an American industry. ARTHUR L. DAY. *Jour. Frank. Inst.*, **190**, 453-72 (1920).—The future of the industry must remain vague. Three firms entered this field, to produce optical glass on a large scale for war purposes, of whom two were able to make use of the product in instruments of their own manufacture. This portion of the industry may endure in whole or in part. The third successful producer of optical glass has to find his market outside his own plant, and this market is rather too intangible to be attractive as a business venture. The cost of several of the necessary ingredients is necessarily greater in this country than in European countries where similar products originate. In quality our raw materials are equally good, our experience in technique is adequate if not equally extensive with some of our European contemporaries, but the cost of potash, for example, will always lay a burden upon the American product, and other ingredients might be mentioned which fall in the same category. If there were a market sufficient to stimulate production on a very large scale these difficulties could be overcome by improved technique and organization, as in the case of other conspicuous American industries, but the demand for optical glass will probably never be large, and the incentive to large-scale processes and cheaper production will therefore probably always be lacking unless the Government determines upon a definite program of preparedness. The instrument maker may find it advantageous to make his own glass for the reason that he can then arrange for the precise optical constants which he wishes to use in his instrument, and he may have them within a period of a few days instead of

weeks or months, but the trade itself will perhaps never furnish sufficient incentive to build up a large industry in this country. Successful makers of optical glass in other countries have had to look for their profit in other lines rather than in their optical products.

A. J. LAMBERT.

PATENTS

Manufacture of window glass. CLYDE S. ROBB. U. S. 1,356,739, Oct. 26, 1920. The manufacture of window glass cylinders with the operation of upward drawing from a molten bath and simultaneously effecting a twisting of the cylinder wall between the bath and the cylinder in formation.

Wire-glass. VICTOR SHUMAN. U. S. 1,355,625, Oct. 12, 1920. A fire resisting body, comprising a sheet of wire-glass, a sheet of plate glass, and an interposed layer of organic material.

Cutter or gripper for use in drawing sheet-glass. HUDSON D. CAMPBELL. U. S. 1,355,449, Oct. 12, 1920. A cutter and gripper formed of carbon for use in connection with the drawing of sheets of glass.

Means for transferring glass to molds. LEONARD D. SOUBIER. U. S. 1,356,174, Oct. 19, 1920. An apparatus with means to supply a stream of molten glass with a traveling mold, a transfer cup traveling therewith, and the means to shift the cup from a position beneath the stream of glass to a position over the mold and discharge the glass into the mold.

C. M. SAEGER, JR.

Glass manufacture. CORNING GLASS WORKS. Brit. 145,428, June 17, 1920. Relates to the compn. of glass specially suitable, as regards expansion, viscosity at working temps., and resistance to devitrification, for the manuf. of elec. lamp bulbs. According to the invention, the glass contains the following constituents in the proportions stated, *viz.*: SiO_2 100 molecules, Na_2O 20-36 molecules, and at least one of bivalent alk. earth oxides 6-36 molecules. The specification gives 9 batch formulas by way of example, the fifth being as follows: SiO_2 100 mols. (or 63 per cent), Na_2O , 25.5 mols. (22.2 per cent); MgO 7.7 mols. (6.2 per cent), and CaO 7.9 mols. (8.8 per cent). C. A.

Furnace for manufacturing glass. K. HAYASHI AND K. OKADA. Jap. 35,595, Dec. 27, 1919. C. A.

Whiteware and Porcelain

The lead question in ceramic industries. L. PETRIK. *Sprechsaal*, 53, 405-8 (1920).—When alkalies or borax are used in lead glaze frits they make the same soluble. Lead frits containing no alkalies or borax on the other hand are insoluble. Soluble lead frits are dangerous in causing lead poisoning among potters. By making two frits, one containing all of the lead oxide with no alkalies or boric acid and another containing all of the alkalies and

boric acid, the amount of soluble lead oxide is greatly reduced. P. recalculated a number of commercial glaze frits preparing a high lead and a high alkali frit in the place of the poisonous alkali-lead frit.

Two high lead frits were used of the following composition:

| | | |
|-------------------------|---|---|
| Frit. No. VII—0.774 PbO | } | 0.134 Al ₂ O ₃ . 2.374 SiO ₂ |
| 0.055 CaO | | |
| 0.044 K ₂ O | | |
| 0.127 Na ₂ O | | |
| Frit No. XII—0.75 PbO | } | 0.12 Al ₂ O ₃ . 2.4 SiO ₂ |
| 0.20 CaO | | |
| 0.05 K ₂ O | | |

Frit. no. VII, of which dil. HCl dissolves 1.0 per cent lead oxide, was used for the preparation of low melting glazes and frit no. XII, of which dil. HCl dissolves 0.55–0.60 per cent lead oxide, is used for the preparation of the higher maturing glazes. Using combinations of these frits the soluble lead oxide was decreased from 31.7 per cent to 0.76 per cent in one glaze, from 23.05 per cent to 0.3 per cent in a second, and in another from 20.72 per cent to 0.25 per cent. Pandemit (natural calcium borate) may be used in the place of the leadless frit. By preparing a tin glaze by the use of the two frits given above, the percentage of soluble lead oxide was reduced from 4.18 to 1.03 per cent. The presence of CaO reduces the solubility of frits. The amount of lead oxide soluble in dil. acid according to Thorpe's method should be less than 1.00 per cent.

H. SCHURECHT.

Frits for whiteware glazes. ANON. Bur. Standards, Tech. News *Bull.* No. 43 (1920).—A special investigation has been undertaken of various mixtures of feldspar, boric acid, and whiting to determine the most satisfactory mixture of these materials for use in white ware frits and also to discover the most economical and efficient method of the manufacture of such frits.

E. T. RODGERS.

PATENTS

Porcelain cement. PORZELLANFABRIK KAHLA. Brit. 145,026, June 14, 1920. A substance having a smaller coeff. of expansion than porcelain, *e. g.*, quartz glass, is added to cement to produce a compn. for cementing porcelain.

C. A.

Enamels

The fish scaling of ground coat enamels. ANON. Bur. Standards, Tech. News *Bull.* No. 43 (1920).—The study of the cause and control of fish scaling of ground coat enamels has been continued, by the preparation of two series with a total of 14 enamels, in one series the felspar being high, while in the other the quartz is high. In each series the fluxes are varied in a systematic manner. The results obtained thus far agree with those for gray ware

enamels, that is, the constituents which tend to promote or retard fish scaling has the same results in the two types of enamels. Furthermore, it was found that there was little tendency to fish scale in three-coat enamels applied to low copper steels which agrees with the results obtained with one-coat enamels. The determinations of the thermal expansion of various types of enamels used for coating sheet steel are being continued.

E. T. RODGERS.

Artificial cryolites. ANON. *Z. angew. Chem.*, **33**, I, 200 (1920).—Description of patent granted the firm of J. L. Eckelt. HF is drawn from the vessel in which it is generated by a water-jet vacuum-pump actuated by a soln. of Na_3AlO_3 . The cryolite separates as a fine cryst. powder which does not clog the pump. The advantages of the method are: Attainment of the end-product by two manipulations (the fusion of kaolin and soda and the action of HF on these); great simplification of equipment and decrease of attendant costs; no escape of HF from the app. and hence plants can be erected in cities.

C. A.

Brick and Tile

Clays for hollow block. ANON. *Brit. Clayworker*, **29**, 169-70 (1920).—Hollow block are increasing in popularity because they are easily produced, are relatively cheaper, cost less for transportation and are much more rapidly laid than solid brick. Hollow block should be (1) hard, (2) impermeable to water, (3) strong and (4) correct in shape. To secure these qualities the clays used must vitrify at comparatively low temps. without losing their shape, so a clay high in lime would be undesirable. Shales and low grade fire clays are usually satisfactory since they contain more desirable fluxes. An economical temp. to fire block is cone 1A, 1100°C . H. G. SCHURECHT.

PATENTS

Apparatus for burning brick. WILLIAM W. DICKINSON, JR. U. S. 1,355,821, Oct. 19, 1920. A number of brick kilns each having its interior part of bricks loosely piled and formed with eyes or arches, and having its top and sides formed of bricks closely piled. One of the sides of each kiln is formed with a vertical passage way which communicates at its upper end with the interior of the kiln adjacent to its top and is formed at its lower end with an opening and a movable conduit adapted to connect the opening with the eyes or arches of the succeeding kiln.

C. M. SAEGER, JR.

Cement and Lime

The manufacture of lime for chemical and metallurgical purposes. I. RICHARD K. MEADE. *Chem. Met. Eng.*, **23**, 841-4 (1920).—Kilns employed for burning lime are intermittent, pot, rotary and shaft. The shaft may be of a mixed feed or separate feed type. Intermittent kilns are primitive, uneconomical and seldom used except for burning lime for the farm. In the

mixed feed shaft kiln, the fuel is mixed with the limestone to be burned. In the separate feed shaft kiln the fuel is burned in fire boxes in the base of the shaft. The mixed feed kiln is more economical of fuel but gives a product contaminated with ashes and therefore the separate feed type is preferred for better grade lime. A shaft kiln commonly consists of steel cylinders lined with fire-brick. A few kilns have been built with reinforced concrete taking the place of the steel cylinders and have proven satisfactory. A strong draft is requisite for burning lime. The most satisfactory method is the use of induced draft but forced draft is employed in some cases. One ton of good bituminous coal hand fired will burn from $3\frac{1}{2}$ to 4 tons of lime. The same fuel used in a gas producer will burn from $3\frac{1}{2}$ to 5 tons. One barrel of fuel oil will burn from 1 to $1\frac{1}{4}$ tons of lime. One cord of seasoned hard wood will burn from $2\frac{1}{2}$ to $2\frac{3}{4}$ tons.

A. J. LAMBERT.

The effects of Cal as an accelerator of the hardening of portland cement mixtures. ROY N. YOUNG. *Tech. Paper*, Bur. Standards, No. 174.—Cal is essentially an oxychloride of lime in a powdered form. It is readily decomposed by water into calcium chloride and calcium hydroxide, the property of accelerating the hardening of portland cement, being due to the former product. The chief advantage of using Cal rather than calcium chloride is the much greater convenience with which it may be handled.

The setting-time of portland cement mixtures was hastened by the addition of Cal to an extent which is considered very desirable in certain types of concrete construction, especially floor toppings, for the reason that the finishing operation may proceed with much less delay. Tests on quick-setting cements indicate that such cements may be made normal by the addition of Cal. It is also shown that unsoundness may be greatly improved or entirely overcome by this treatment.

The early hardening of portland cement mixtures is hastened by the addition of Cal. The strength of mortars was increased from 40 per cent to 140 per cent, and the strength of concrete from 52 per cent to 135 per cent at the age of two days by an addition of Cal equal to 5 per cent of the cement. Comparison tests, in which commercial calcium chloride was used as the accelerator, indicate that the general effect of Cal is practically the same as might be expected from the use of equivalent amounts of calcium chloride and hydrated lime.

No conclusions were drawn from very limited corrosion tests, but it is advised that caution be exercised in the use of Cal in concrete containing steel reinforcing if the concrete is to be freely exposed to the weather or excessive dampness.

A. J. LAMBERT.

Tests with iron blast furnace slag. H. BURCHARTZ. *Stahl u. Eisen*, 40, 814-9 (1920).—Tests extending over a period of five years on the use of slag in reinforced concrete indicate that the slag undergoes no physical or chemical change and is entirely satisfactory for such use.

C. A.

ACTIVITIES OF THE SOCIETY

Actions of the Board of Trustees

November 10, 1920. It was voted to approve the appointment by President Minton of the following:

George H. Brown, Chairman, Committee on Research and Development.

A. F. Greaves-Walker, Chairman, Refractories Division.

L. V. Solon Temporary Chairman, Division of Ceramic Decorative Processes.

Frederick H. Rhead, Temporary Secretary, Division of Ceramic Decorative Processes.

November 23, 1920. It was voted that, beginning January 1, 1921, the annual dues of Associate Members shall be \$7.50.

Report of the Nominating Committee

To the Voting Members of the American Ceramic Society:

The Nominating Committee makes the following report on nominations for officers for the year 1921-1922:

President, F. K. Penec, American Eneastic Tiling Co., Zanesville, Ohio.

Vice-Pres., F. B. Ortman, Northwestern Terra Cotta Co., Chicago, Ill.

Treasurer, R. K. Hursh, University of Illinois, Urbana, Ill.

Trustee, R. M. Howe, Mellon Institute, Pittsburgh, Pa.

Excerpt from the Rules

"Any five Active Members may act as a self-constituted Nominating Committee and present the names of any nominees to the Secretary, provided this is done at least thirty days before the annual meeting. The names of the nominees, provided their assent has been obtained before nomination, shall be placed on the ballot without distinction as to nomination by the regular or self-constituted Nominating Committee and shall be mailed to each Active Member, not in arrears, at least twenty days before the annual meeting."

Entertainment of the Ladies at the Next Convention

To the Ladies:

Are you coming to the next annual Convention of the American Ceramic Society, February 21st to 24th. If not, why not?

The ladies are attending in increasing numbers each year and the social features of the convention are becoming of distinct importance. If you hope to attend, communicate with me at your earliest possible convenience.

Cordially yours,

(signed) Mrs. ARTHUR S. WATTS,
1764 North High St.,
Columbus, Ohio.

A Letter to the Members of the Terra Cotta Division

DEAR SIR:

Every one who attended last year's meeting of the American Ceramic Society realized the value and importance of having the Terra Cotta Division meeting separate from the main portion of the meeting. They realized that this greatly facilitated the open and free discussion of subjects of common interest to the terra cotta industry and allowed plenty of time for the reading and discussion of the nine important papers that were submitted. This also allowed the members to hear such other papers on continuous kilns, drying, glazing, etc., as were presented by the other divisions without having to waste time listening to unimportant topics.

To maintain this advantage for the Terra Cotta Division this year, it will be necessary for us to produce a good program of terra cotta papers and discussions.

I wish to urge, therefore, that the titles of such investigations as you now have under way and which you expect to have ready for the meeting, be sent to me at once so that the program can be arranged. I hope that each company will participate in some manner this year: either by submitting a paper or by leading on open discussion on some terra cotta subject. Each company certainly has some problem on which they are working, and should be glad to have the opinion of the other members on this particular subject. Send in the topic in which you are interested and it will be listed for open discussion at the meeting. This is one of the greatest benefits which are offered by our division.

Please answer this as promptly as possible.

Yours very truly,

R. L. CLARE,

Secretary Terra Cotta Division.

Meeting of the Chicago Section

The annual meeting of the Chicago Section was held at the City Club on the afternoon of November 27th. At the business session held directly after lunch, the following officers were elected for the coming year: B. S. Radcliffe, Chairman; F. L. Steinhoff, Vice-Chairman; W. W. Wilkins, Secretary-Treasurer; C. W. Parmelee, Councilor; H. E. Davis, Chairman, Program Committee; E. A. Brockman, Chairman, Membership Committee.

The following papers were read:

"Porcelain Enameling Furnace," by C. G. Armstrong. The first part of this paper was historical, dealing with the art of enameling from 1300 B. C. up to the present time. The second part dealt with enameling furnaces and especially with a new design in which carborundum refractories are employed and the regenerative principal is used.

"Spark Plug Porcelains," by W. W. Wilkins. The author stated that 75% of all failures of spark plugs is due to faulty mechanical design; 25% -

of the failures can be traced to the refractory material. Tests have shown that zirconium refractories give remarkable results in spark plugs.

A third paper by R. Rodchouse described the oil-gas furnace for burning enameled ware developed by the author. The furnace has no muffle, employs no special shapes in construction and is stated to have remarkably long life.

F. L. STEINHOFF, *Secretary*.

New Members Received during November

Resident

Goodner, Ernest F., 5502 Sixteenth Ave., S. E., Seattle, Wash., Graduate Student, University of Washington.

Holmes, M. E., Ph.D., 918 G St., N. W., Washington, D. C., Manager, Chemical Dept., National Lime Association.

Luepke, Emil J., 2001 S. Kingshighway, St. Louis, Mo., Foreman, Quick Meal Stove Co.

Merica, Paul D., Ph.D., Bayonne, N. J., Supt. of Research, International Nickel Co.

Perg, Carl, 609 W. Kalamazoo Ave., Kalamazoo, Mich.

Short, Frank, 3411 Walnut St., Philadelphia, Pa., Expert in Aircraft Armament, Ordnance Dept., Frankford Arsenal.

Foreign

Solon, G. C., Royal Porcelain Works, Worcester, England Managing Director.

White, G. N., D.Sc., 7 Victoria Ave., Worcester, England, Research Chemist, Royal Porcelain Works.

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